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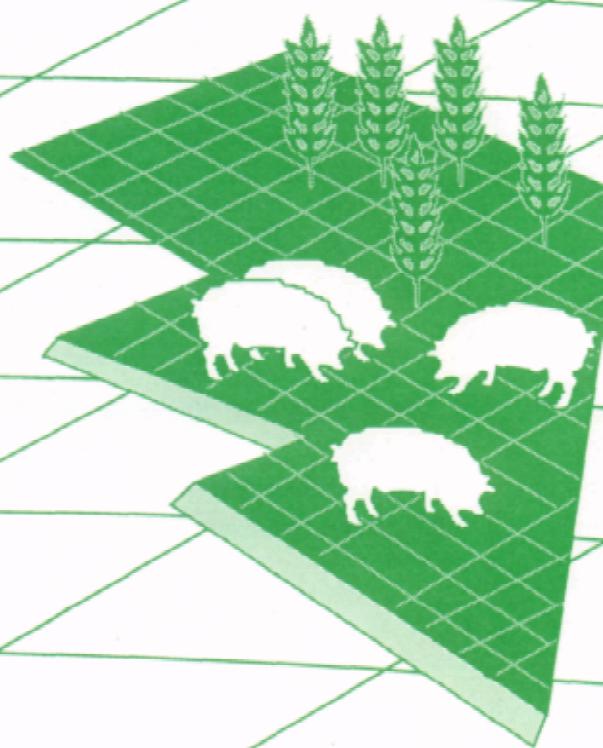
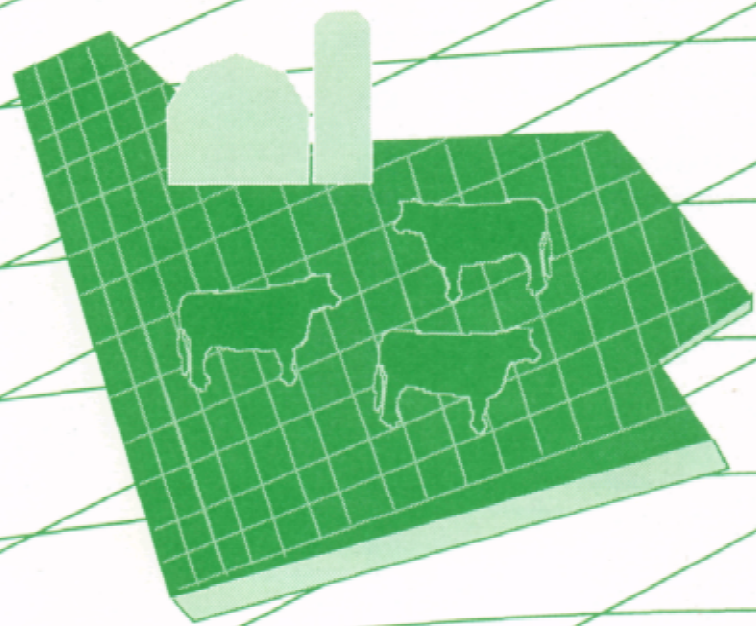
Urbanization of Rural Land in the United States

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Abstract

While urban area increased rapidly during the 1970's, it was a small percentage of total land area. Cropland and pasture losses were comparatively small. Conversion of other rural land to cropland and pasture replaced more than one-third of losses to urban uses. "Land consumption" by urban uses has remained constant at about a half acre per household in fast-growth counties since 1960. The most rapidly growing counties had the highest land conversion rates. Higher rates also occurred in counties with smaller initial populations than in counties with larger population bases. However, these counties accounted for little total land conversion. Projected urban land conversion will not significantly reduce the U.S. cropland base by the year 2000. Increases in agricultural production due to technological change should more than compensate for projected cropland losses. Urbanization of agricultural land does raise issues at the State and local levels in regard to protecting watersheds, maintaining air quality, maintaining open space, preserving rural lifestyles, preventing urban sprawl, and preserving local economies.

Keywords: Agriculture, change, conversion, farmland, fast-growth, land, prime, rural, urban, urbanization

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Loss of Farmland to Urban Uses Poses No Threat to U.S. Food and Fiber Production

Losing farmland to urban uses does not threaten total cropland or the level of agricultural production, which should be sufficient to meet food and fiber demand into the next century.

About 740,000 to 1 million acres of rural land were converted to urban uses each year in the 1970's, the latest period for which reliable data are available. Residential uses, the largest component of urban land, increased by nearly 50 percent during the decade. One-third of urban increases came from cropland and pasture, while another one-third came from rangeland. But, despite losses to urbanization, cropland has remained nearly constant since World War II. Urban land is about 2.5 percent of U.S. land area, so even a large increase in urban areas involves little land in proportion to the U.S. total. If the 1980-2000 U.S. rate of urbanization continues at the 1960-80 rate, U.S. urban area would reach 66 million acres by 2000, less than 3 percent of the total U.S. land area.

This report examines the effects of urban conversion on rural uses of land. Analysis of land use change, related to population and household growth, is presented for the period from the early 1970's to the early 1980's and compared with results of a similar study of the 1960's. Data were interpreted from aerial photography for 135 fast-growth counties (counties that grew by at least 25,000 persons and by at least 25 percent between 1970 and 1980). The study counties are primarily rural-urban fringe counties located in fast-growing areas. These 135 study counties accounted for 47 percent of the 1970's population increase in the United States.

Population and household increases are the primary forces affecting urban land use. Regional differences in urban land conversion are affected by population longevity, retirement trends toward the Sun Belt States, changing marriage and divorce rates, birth rates, and changes in the number of persons per household. Land for new urban development comes from rural uses, including cropland, pasture, forest land, and rangeland.

Land Use Change Is Dynamic

Except for urban uses, land use change is dynamic, shifting from one use to another. Urban uses are considered an absorbing category. That is, urban land grows by taking land from other uses, but urban uses rarely revert to other uses. For example, urban uses increased 37 percent during the 1970's, but less than 1 percent of urban land was converted to rural uses. Once developed, land stays in urban uses.

Although a third of new urban uses came from cropland and pasture, 706,000 acres of rangeland were converted to cropland during the decade, replacing some of the cropland lost to urban conversion. Another 319,000 acres shifted from cropland to range, further illustrating the dynamic nature of land use change.

Urban Conversion Rate Was the Same From 1960 to 1980

The average rate of urbanization in the 1970's, 0.46 acre per new household, was the same as in the 1960's. Counties with smaller initial populations had higher marginal rates. Counties that grew most rapidly had the highest land conversion rates, but accounted for relatively little urban land conversion. Southeastern counties had the greatest rate of expansion in urban area, about 0.54 acre per household.

Urban Land Conversion Affects Prime Land No More Than It Affects Other Land

Fast-growth counties had a smaller proportion of prime cropland (land that is physically best suited to producing food and fiber, according to the U.S. Department of Agriculture) than the U.S. average and proportionately less prime cropland was converted to urban uses. Forty-three percent of cropland in fast-growth counties is prime,

compared with 49 percent for the Nation. Furthermore, of cropland converted, 40 percent was prime. Prime cropland and pasture converted from other rural uses replaced about one-third of the prime cropland lost to urban uses. The largest concentrations of fast-growth counties are located in Florida, Arizona, and southern California, where there is little prime land. Other areas that have heavy concentrations of prime land, such as Iowa, Illinois, Indiana, and Kansas, have few fast-growth counties.

Small Urban Area Change Estimated Through 2000

If the 1980-2000 U.S. rate of urbanization continues at the 1960-80 rate, projected U.S. household growth would annually add about 860,000 acres of urban area by the year 2000. Urban area in the United States would total 66 million acres by 2000. That is less than 3 percent

of the total U.S. land area. Conversion of new cropland and increased production per acre would likely offset projected cropland losses to urbanization.

State and Local Concerns

Urban land conversion has little effect on national food and fiber production. However, at State, regional, and local levels, urbanization of agricultural land affects efforts to protect watersheds and maintain air quality, and to maintain open space, preserve rural lifestyles, prevent urban sprawl, and preserve local economies. Present Federal policy is aimed at helping State and private groups to identify harmful effects on farmland and to ensure compatibility of Federal programs with State and local farmland protection programs.

Farmland Loss to Urban Uses Will Not Significantly Reduce U.S. Food and Fiber Production

Despite losses to urbanization, cropland has remained nearly constant since World War II

- Urban land is only 2.5 percent of U.S. land area, so even a large percentage increase in urban area involves little land in proportion to the U.S. total.
- Cropland and pasture are eight times larger than urban area, so large additions to urban area involve little cropland loss.
- Nearly two-thirds of new urban growth comes from land in forest and range uses, not productive cropland.

In the fastest growing counties during the 1970's:

- Urban land increased 37 percent, but cropland and pasture decreased only 4 percent.
- Only a third of new urban land was formerly cropland or pasture.
- Additions to cropland and pasture offset about one-third of gross losses to urban uses.
- While 43 percent of fast-growth county cropland and pasture was prime farmland, only 40 percent of urbanization occurred on prime cropland and pasture, rated as our best farmland.

The amount of land urbanized for each new household added in fast-growth counties has remained nearly constant since the 1960's

- The rate of urbanization, about one-half acre per new household, was the same for the 1970's as the 1960's.
- Counties in earlier stages of growth (low population but large percentage increases) urbanized more land for each new household than more developed counties.
- Southeastern and Southwestern Sun Belt counties had the largest expansion in urban area and urbanized the most land per household.
- Metro counties urbanized the most land, but rural counties added more land per household.

Urban Conversion of Cropland and Other Rural Land--Background

Urban expansion uses agricultural land, rangeland, forest land, and other rural land. The quantity and rate of conversion affects national food and fiber production, rural economies, environmental quality, and other socioeconomic factors. This report examines the effects of urbanization on agriculture.

Estimates of Cropland Loss

The loss of agricultural land to urban uses motivated the Economic Research Service (ERS), U.S. Department of Agriculture (USDA), to identify and quantify these losses. Previous studies were often inadequate and gave inconsistent answers about the rate of urban land conversion.

Agencies measure urban land area for different reasons, using different definitions, criteria, and standards. Thus, different measures of urban area are not consistent. Agencies seldom determine both beginning and ending land use during a specific period. Such data sources do not capture actual land use changes. Urban definitions are thus not consistent over time, resulting in misleading trends. Some previous studies include the following.

The National Agricultural Lands Study (NALS)

Controversy about the amount of land lost to urban uses resulted in a major national study in 1981 of the loss of farmland and the adequacy of farmland to produce food and fiber. NALS claimed that the annual rate of conversion of agricultural land to urban uses was nearly 3 million acres (NALS, 1981).¹

In a critique of NALS, Vining pointed out that "If one third of the land converted is prime farmland . . . then clearly we are not much more than a generation away from exhausting this reserve" (Vining, 1982). Vining went on to dispute the reliability of the NALS data. Fischel showed that the data behind the NALS 3-million-acre figure overstated the annual conversion " . . . by at least a factor of 2, and quite possibly by a factor of 3 or 4 . . ." (Fischel, 1982). Brewer and Boxley questioned the accuracy of NALS by pointing out that basic land uses were not adequately defined (Brewer and Boxley, 1981) (see box, "Differences Between Rural Land, Farmland, Agricultural Land, and Cropland"). Several other authors found fault with NALS (Brown and others, 1982; Lee, 1984;

Platt, 1985; Raup, 1981 and 1982; Simon and Sudman, 1982).

The Second RCA (Resources Conservation Act) Appraisal

This study used lower annual loss figures: from 0.9 to 1.1 million acres for most of the 1960's, and from 1.8 to 2.1 million acres from 1967 to 1977 (USDA, 1990c). The Second RCA and NALS both used data from the 1977 National Resources Inventory (NRI) (USDA, 1982), but the RCA attempted " . . . to correct for overcounting . . ." (USDA, 1990c).

Census Urban Area

The U.S. Department of Commerce, Bureau of the Census, estimates urban area for the Census of Population, taken every decade. According to the census, urban area in the United States increased from 25.5 million acres in 1960 to 55.9 million acres in 1990 (fig. 1). Estimates of census urban area include pockets of rural uses within mapped urban areas. Thus, census estimates may overstate the amount of urban area and the extent of changes over time (Frey, 1983).

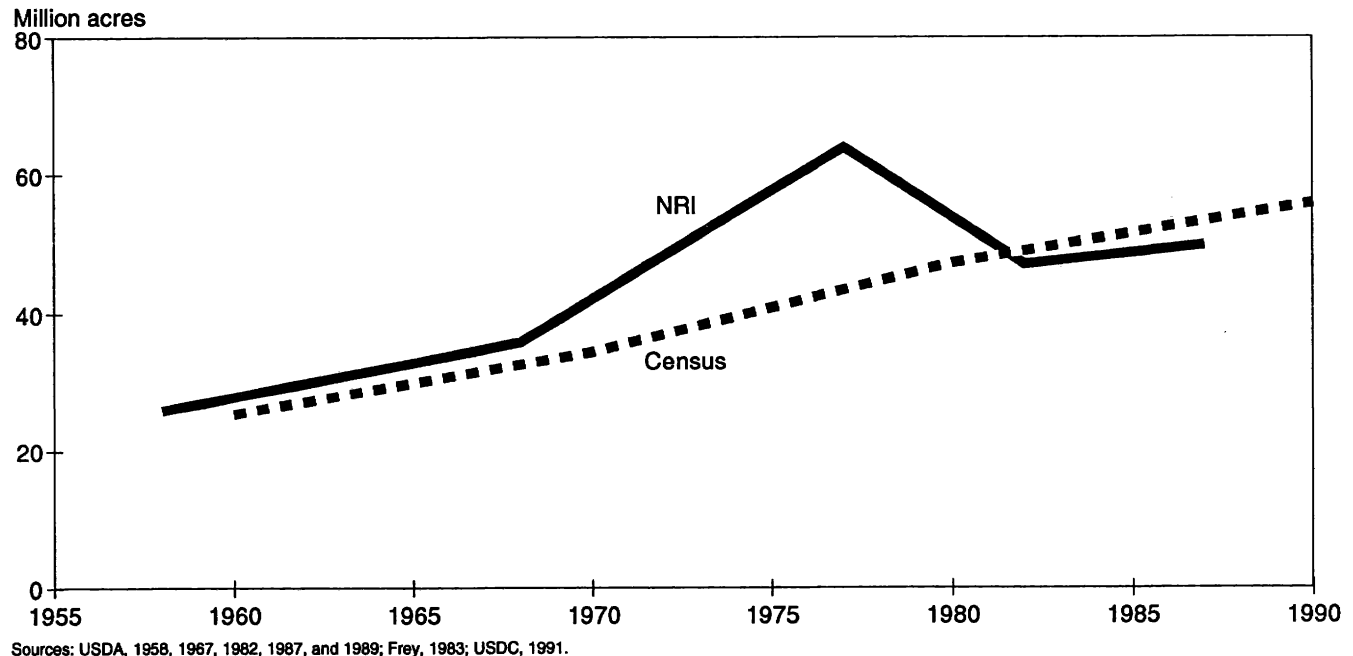
The National Resources Inventory (NRI) and the Conservation Needs Inventory (CNI) include developed uses outside urban areas delineated by the Bureau of the Census (USDA, 1958, 1967, 1982, 1987, and 1989; Frey, 1983). Inaccurate mapping of urban boundaries in 1977 resulted in an overestimate of urban area, which was corrected in 1982 (Lee, 1984; USDA, 1990c). These problems, and failure to obtain land use changes into and out of each use, made existing data unreliable. ERS used paired-point random sampling to derive land use change for the 1970's, which is better suited to answer questions about the dynamics of land use change.

¹Names in parentheses refer to sources listed in the references at the end of this report.

Figure 1

Measures of urban area, 1958-90

According to census estimates, urban area in the United States increased by 30 million acres from 1960 to 1990.



Differences Between Rural Land, Farmland, Agricultural Land, and Cropland

Confusion exists regarding the definitions of rural land, farmland, agricultural land, and cropland. These terms are often used inconsistently to denote the same area. Insufficient distinction has been made between "agricultural land," "cropland," and "farmland" (Brewer and Boxley, 1981).

This report distinguishes among these categories of land use.

- Rural land includes anything not urban. Rural land includes agricultural land and all other nonurban land.
- Agricultural land includes farmland, non-Federal rangeland, and any land not in farms that is used for crops or pasture, such as portions of wildlife refuges in crops or pasture. Agricultural land excludes nonurban rural land, such as forest land, parks, roads, and wildlife refuge areas not in crops or pasture.
- Farmland consists of land in farms, including cropland, pasture, and land that is part of a farm but not used for producing crops or livestock. Over one-half of all rural land is not in farms (see table 1, in section, "Land Use in the United States"). The 1987 U.S. Census of Agriculture defines a farm as any place generating at least \$1,000 in product sales (USDC, 1989a). Most cropland and pasture (95 percent), rangeland (69 percent), and some forest land (11 percent) are included in farms. The remaining cropland and pasture are not owned by farmers. Public rangeland grazed on a permit basis and most forest land, for example, are not included in land in farms. These include land managed by the Bureau of Land Management, U.S. Department of Interior, and the Forest Service, USDA.

The Amount and Impact of Cropland Losses Are Important Issues

The rate and quantity of cropland loss are issues at the Federal, State, and local levels.

The Federal Issue

Urbanization of cropland can be both a Federal and a local issue. There are many facets of the issue intertwined in the physical, economic, and political disciplines (Brewer and Boxley, 1981; Anderson and others, 1975; Peterson, 1974). Furthermore, these facets have different levels of intensity over time. For example, the adequacy of cropland became an issue during the 1970's when rising commodity prices, increased exports, and the Soviet grain agreement prompted an interagency effort to look at present and future availability of cropland (NALS, 1981).

The production of adequate quantities of food and fiber to supply the country is seen as a national issue. The United States has been a surplus producer of food for many years. There is little worry about meeting foreseeable export demand (Barrows and Troutt, 1990). That does not mean that the United States could not be a deficit producer of some major crops in the future. Also, some specialty crops that can be grown only in certain areas of the country with unique climates or special soils may be in short supply due to urban encroachment.

Urbanization of cropland becomes a Federal issue when cropland is taken by Federal programs for other purposes, such as the interstate highway system, military bases, national parks and recreation areas, and a number of other uses for which the Federal Government acquires land. While not always related to urban land conversion, Government acquisitions that involve cropland are often irreversible. At issue is whether it is in the public interest to accomplish these national goals by taking cropland or by substituting land in other uses.

The Federal Government's present role in land use regulation is mostly limited to encouraging Federal agencies to consider the effects on farmland of Federal agency land acquisitions, and to provide pilot project loan guarantees and interest rate assistance for loans made by lending institutions

to State trust funds that invest in the protection or preservation of farmland for agricultural purposes, such as purchase of development rights programs (P.L. 97-98 and P.L. 101-624). The Federal Government's role is modest because the impact of urban land conversion on U.S. agricultural production capacity is small and most other farmland protection issues are State and local.

State and Local Issues

Maintaining open space, preserving rural lifestyles, and preventing urban sprawl are commonly regarded as State and local issues (see box, "Reasons for Farmland Preservation"). Many of these also become Federal issues because of the political and economic complexities involved. For example, Federal housing programs, construction programs, and favorable tax treatment of home mortgages influence land use patterns in urbanizing areas.

To argue that the federal government has no concern over conversion of agricultural land would be to ignore the impetus of federal policy to the conversion process and the important effects of conversion on other federal interests such as housing and transportation. (Barrows and Troutt, 1990).

Other State and local issues include maintaining viable local agricultural economies with supporting supply and marketing activities and sustaining communities of farm families with their associated rural characteristics. Urban development may not be appropriate in some watersheds because of water and air environmental considerations. Farmland is also sometimes protected for aesthetic reasons to provide open space, preserve rural lifestyles, and prevent urban sprawl. Some issues that may not be especially important at a particular point in time at the Federal level can still be State and local issues: for example, production of warm-climate vegetables and other specialty crops.

Reasons for Farmland Preservation

Effective land use planning

- Maintain open space
- Preserve rural lifestyles
- Prevent urban sprawl
- Control infrastructure costs
- Preserve local economies

Environmental quality

- Preserve watersheds
- Maintain air quality

Natural resource conservation

- Conserve prime, unique, and locally important farmland
- Conserve energy
- Retain natural systems and processes

Food and fiber production

- Maintain agricultural production capacity
- Maintain specialty crops
- Promote local self-sufficiency

It Is Important To Have Accurate Information on Urbanization

Many Federal, State, and local programs address issues related to urban conversion of agricultural and other rural land.

Why Study Urbanization?

It is important to know the quantity and rate of urbanization because many Federal, State, and local programs address issues related to urban conversion of agricultural and other rural land. If these programs are based on accurate information about the amount, quality, and rate of land converted, then plans can be formulated to better meet program objectives, or perhaps, in some cases, reduce or phase out programs.

Programs to regulate land use come in many different forms, but basically fall into six major areas (see box, "Programs That Affect Farmland Preservation"). In the United States, regulation of land use is a power given to the States and is often delegated to local governments. As these governments address concerns arising from farmland loss, several different program approaches have evolved. Most farmland retention programs seek to ameliorate differences between developed and farmland uses or strengthen institutions expressing public support for farming as a preferred land use.

The Nature of Urban Land Conversion

Seventy-three and 75.8 percent of the 1980 and 1990 U.S. population, respectively, lived in urban areas, which comprised less than 3 percent of the U.S. land area in both decades (Frey, 1983;

USDC, 1991). Rural-to-urban conversion of land occurs fastest in and near rural-urban fringe areas. Anecdotal news accounts and some studies leave the impression that rural land, especially cropland, is being urbanized at too rapid a rate (Simon, 1990; NALS, 1981; Sampson, 1981). Another perception is that cropland lost to urban uses is not replaced. In fact, studies have shown that some cropland is replaced, in part, by other rural land, such as rangeland and forest land (Zeimetz, 1976b; Dill and Otte, 1970, 1971). Cropland replacement is not often obvious since it occurs mainly in sparsely settled areas. A third perception is that urbanization changes the nature of adjacent farms into idle, unused land, waiting to be converted to urban uses. But, urbanization also results in increased demand for farm commodities, land, and labor. Farmers near rapidly growing urban areas often react to increased urban demand for specialty crops by growing higher value vegetable, fruit, greenhouse, and nursery crops (Heimlich and Brooks, 1989).

The results of the 1970's fast-growth county study are presented in this report and are compared with a 1960's study and with data for the 1980's. This report presents findings on the amount and rate of rural land conversion, the amount of cropland acreage replaced by other rural land uses, the rate of prime cropland conversion, and the regions of the country most affected by urbanization. Rates of urban land conversion are projected to the end of the century.

Programs That Affect Farmland Preservation

Purchase or Transfer of Development Rights

State and local governments (or developers) pay landowners the difference between market and agricultural use values of farmland in return for permanent agreements to restrict developed uses. Landowners retain ownership and agricultural use rights. Transfer of development rights programs allows developers to increase density in selected areas by purchasing development rights from farmers in other areas. In essence, the developer buys the right to develop in one location and exercises it in another. In 1991, 14 States had purchase-of-development-rights programs and 7 had transfer-of-development-rights programs (American Farmland Trust, 1991; *Farmland Notes*, 1987; Williams and Bills, 1991).

Current Use Assessment

State and local governments reduce farmland property tax assessments from market values, usually residential values, to agricultural use values. As of 1988, 27 States had rollback penalties for conversion within a specified number of years. All States have enabling legislation (Aiken, 1989).

Zoning and Land Use Regulation

States authorize, and local governments or regional bodies implement, exclusive or nonexclusive zones where development is restricted and farming is the preferred use. This category includes State comprehensive planning requiring counties and municipalities to prepare and execute land use plans and ordinances. State or regional land use regulation is directed at controlling growth, usually large developments with multijurisdictional impacts. Thirty States had such regulations in 1991 (*Farmland Notes*, 1987; American Farmland Trust, 1991).

Agricultural Districts

States authorize special districts to administer farmland retention programs (such as current use assessment), require modifications to local regulations to encourage farming as a preferred use, and restrict local government authority to regulate farm structures or acquire farmland by eminent domain. Fifteen States had such programs in 1991 (Bills and Boisvert, 1990; American Farmland Trust, 1991).

Right-to-Farm Laws

State laws protect farmers from certain legal actions on the part of subsequent residents, such as nuisance suits against normally accepted farming practices on established farms. All 50 States have some form of right-to-farm legislation (*Farmland Notes*, 1987; American Farmland Trust, 1991).

Executive or Legislative Orders

State policies declare the importance of agriculture to the State, address the rate and causes of farmland loss, and order State agencies to reduce or restrict activities that would convert farmland. Sixteen States have executive or legislative policies (*Farmland Notes*, 1987; Bushwick, 1990; American Farmland Trust, 1991).

The Economic Research Service Has Studied Urbanization of Cropland Since the 1950's

ERS studies focused on major land uses, the amount of land converted to urban uses, and programs to slow cropland loss.

The Economic Research Service (ERS) conducts studies of land use and urban land conversion in the United States (Heimlich and Anderson, 1987). ERS researchers have compiled a host of secondary sources of land use data to present major land uses in the United States. Earliest work on major land uses included that of Reuss, Wooten, and Marschner (1948). Wooten and Anderson (1957) and Wooten, Gertel, and Pendleton (1962) continued the series through 1959. Frey, Krause, and Dickason (1968) updated the series for 1964. Frey (1973, 1979, 1982) took over and published the next three editions of major land uses. Frey teamed with Hexem (1985) to derive the 1982 analysis. For 1987, Daugherty (1991) published the series. Krupa and Daugherty (1990) placed the data from the major land use series in a computer file, available publicly as one of the ERS-NASS Electronic Data Products.

ERS studies that focus on land use change include the work done by Dill and Otte (1970 and 1971), Zeimetz and others (1976a), and Heimlich and others (1991). These studies provide information unavailable elsewhere about land use change at the rural-urban fringe. The present report is the latest ERS research on land use change and compares the results with earlier studies.

Previous Research of Urban Land Conversion

Changes over time occur both into and out of most land uses. It is important to know the interrelationship of land use changes in order to make future predictions of change and the effects of change. One of the first comprehensive, national studies to consider the losses and gains in each land use category was *Dynamics of Land Use in Fast Growth Areas* (Zeimetz and others, 1976b). Using paired-point sampling procedures on aerial photography to construct land use transition matrices (see section, "Study Methods and Procedures"), Zeimetz and associates described the gross changes, as well as the net changes between land uses.

A constraint on the study done by Zeimetz and associates was a lack of adequate aerial photo-

graphy for all of the 1960's fast-growth counties. This data constraint limited the study to only 53 of the 129 fast-growth counties of the 1960's.

In 1985, Behm and Pease (1985) reported the results of a pilot study in Oregon to examine techniques and data availability that might be used by ERS to study land use change in the 1970's. They concluded that much more aerial photography was available for the 1970's study than for the 1960's study. They also tested spatial sampling approaches and concluded that paired-point sampling offered more accuracy at less cost than proportional sampling.

In 1988, ERS published the results of its examination of techniques, procedures, and data sources for studying land use change in fast-growth counties (Vesterby, 1988c). This study analyzed the probable use of satellite imagery versus several different sources of aerial photography and concluded that only aerial photography could provide the coverage and resolution required for a new study of 1970's urban land conversion. It also confirmed the Behm and Pease conclusion that paired-point sampling would be superior to single date sampling. In addition, this analysis of study methods recommended a preferred sample design and sample size necessary to provide accuracy at the national level and for each of four regions.

Current Urban Land Conversion Research

Using the procedures and techniques from the 1988 examination of study methods, ERS initiated research of urbanization for the 1970's. The objectives sought to explain land use change and related phenomena and to predict future rates of urbanization (Heimlich and Reining, 1990). For the 1970's research of urban land conversion, photography was available for 135 out of 139 fast-growth counties, thus avoiding a major data problem of the ERS study for the 1960's (Freed and Jones, 1988; Vesterby, 1988a, 1988b, and 1988d; Vesterby and Brooks, 1990; Vesterby and Heimlich, 1991; Zeimetz and others, 1976a).

U.S. Urban Area Is Small Compared With Rural Land Area

Rural land area is much larger than urban area, but not all rural land is used for agriculture.

Urban Uses Viewed in the Context of All Land

There were 2.3 billion acres of land in the United States in 1987 (table 1). Of that, 57 million acres, or 2.5 percent, were urban. Rural land accounts for 2.2 billion acres, or 97.5 percent. Rangeland, cropland and pasture, farmsteads and roads, forest land, and other rural land, combined, comprise the rural land uses. Land used for crops and pasture is over eight times as large as urban land area. Of the 57 million acres of urban land, about 59 percent are residential and used for housing (fig. 2). Other urban land is used for commercial, utility, mixed urban, and transitional purposes. Mixed urban refers to land for which no single use

can be discerned and includes recreation areas, such as golf courses. Transition land is land changing from one use to another, such as from forest to construction sites. Most transition land changes to urban residential uses.

More than one-half of all rural land does not qualify as "land in farms" as defined by the Bureau of the Census. Most cropland and pasture (95 percent), and rangeland (69 percent), and some forest land (11 percent) are included in land in farms. The remaining cropland and pasture are not owned by farmers. Public rangeland grazed on a permit basis and most forest land, for example, are not included in "land in farms."

Table 1--Major uses of land, 1987

Rural land accounts for 97.5 percent of all land in the United States.

| Major land use | Land in farms ¹ | Other land | All land ² |
|-------------------------------|----------------------------|------------|-----------------------|
| <i>Million acres</i> | | | |
| Urban | 0 | 57 | 57 |
| Rural | 964 | 1,244 | 2,208 |
| Range | 410 | 181 | 591 |
| Cropland and pasture | 443 | 21 | 464 |
| Farmsteads and roads | 7 | 0 | 7 |
| Forest ³ | 80 | 651 | 731 |
| Other rural land ⁴ | 24 | 391 | 415 |
| Total U.S. land | 964 | 1,301 | 2,265 |

¹USDC, 1989a. "Land in farms" must generate at least \$1,000 in product sales, according to the Bureau of the Census definition of a farm.

²Daugherty, 1991.

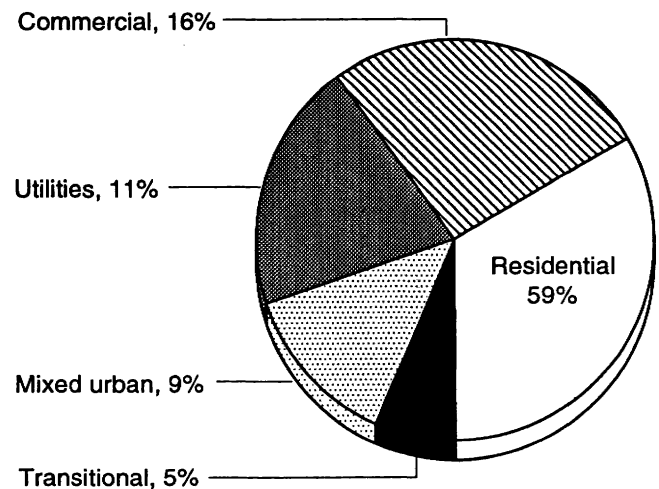
³Includes timberland and reserved timberland, both Federal and non-Federal; parks; wildlife areas; and other special use areas.

⁴Includes areas used for transportation, recreation, defense, swamps, bare rock areas, and deserts.

Figure 2

How urban land is used, 1980

Almost 60 percent of urban land is residential and used for housing.



Source: Vesterby and Heimlich, 1991.

Farmland Has Declined, but Cropland Has Remained Stable

Total U.S. cropland area has remained stable at about 465 million acres since 1950.

Use of Land in Farms

Despite a 16-percent decline in land in farms, there has been little change in the level of cropland and pasture acreage in 40 years (fig. 3). Farmland, rural land, and cropland are not synonymous. Much rural land available for conversion to urban uses is not cropland and is not used to produce food and fiber. In 1987, 2.2 billion acres in the United States were rural, but less than one-half of that was farmland (Daugherty, 1991; USDC, 1989a). Less than one-half of the farmland was cropland and pasture. Most of the decrease in farmland was forest land, rangeland, and land in other farm uses. While not involved with the production of food, these uses are important because they relate to concerns about open space, aesthetic values, and environmental factors.

Cropland in the United States has remained relatively stable at an average of about 465 million acres since 1950. Of total cropland, about 77 percent is used for crops, 15 percent for pasture, and about 8 percent is idle. While these percentages vary from year to year, the total remains fairly constant (Daugherty, 1991).

What Will Happen to the Size of the Cropland Base in the Future?

No one knows for sure. But land is available for conversion to cropland and pasture. Hexem and Krupa (1987) estimated that 35 million acres have high potential for crop use and 117 million more have medium potential. In the past, high commodity prices have brought more cropland into production.

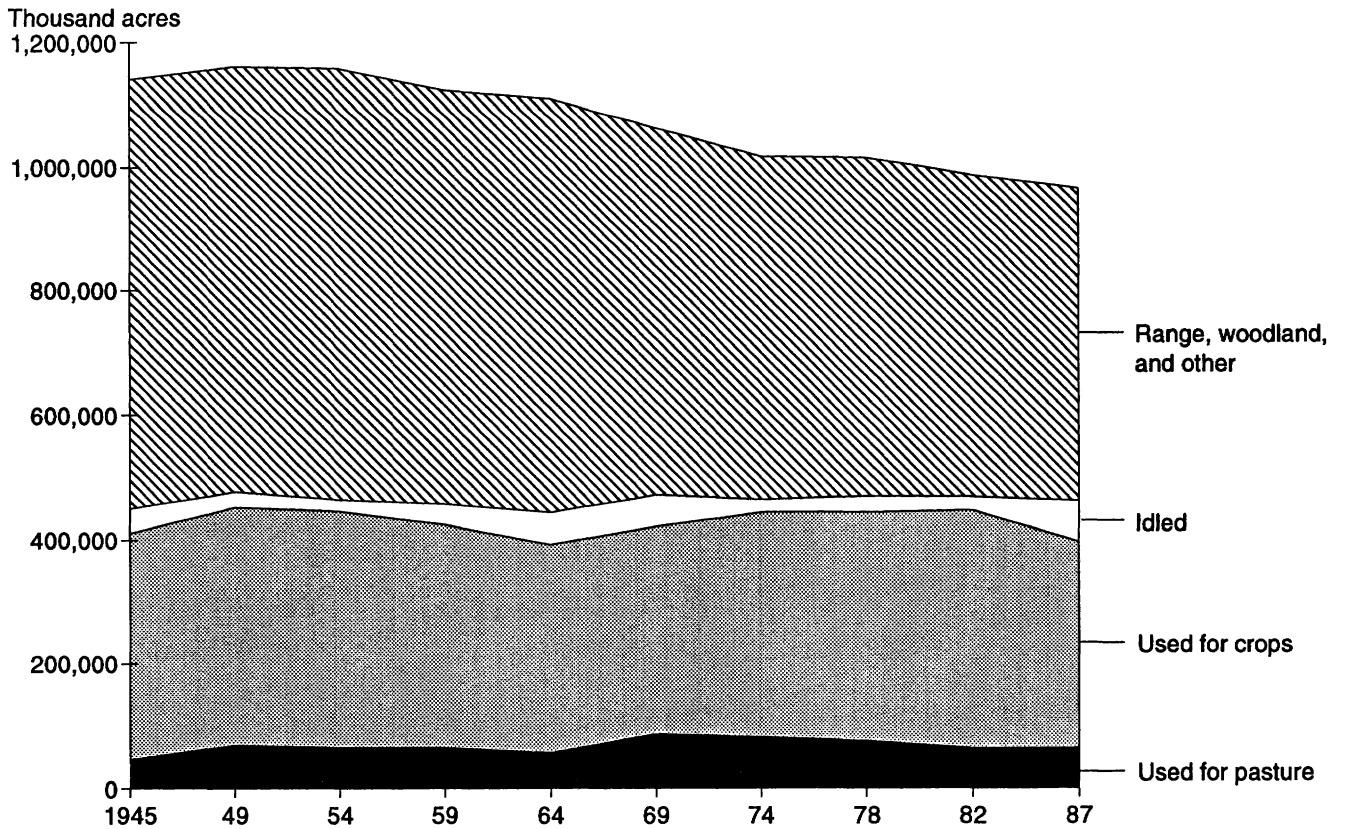
Farmers' ability to convert wetlands, highly erodible land, and other environmentally sensitive land for crop production has been increasingly constrained. Swampbuster and sodbuster provisions of the 1985 Food Security Act and the 1990 Food, Agriculture, Conservation, and Trade Act and numerous State and local environmental and conservation laws reduce the amount of land that can be brought into production. Economic incentives for cropland development have also been reduced by the 1986 Tax Reform Act, which limits deductions for land clearing and drainage and eliminates preferential capital gains treatment.

Urban area is small and new urban conversions are only about one-third cropland. Thus, it would take very large increases in urban area to have any significant effect on cropland in the near future.

Figure 3

Use of land in farms, 1945-87

Land in farms has decreased, yet total cropland has remained constant.



Sources: Daugherty, 1991; Krupa and Daugherty, 1990.

Land Is Dynamic, Changing Uses During a Decade

Major land uses shift over time.

How permanent are changes in land use? Land shifts from one use to another as economic factors favor different resource uses at different times (fig. 4). With the exception of urban uses, changes occur to and from most major land uses. To varying degrees, land changes from less developed or improved uses, such as forest land or rangeland, to more developed uses, such as cropland or residential uses.

Changes in Land Use

Gross changes are total additions or total subtractions to a land use (fig. 5). For example, gross change in cropland is the loss of cropland during a decade without considering new land that was brought into production. Net change takes into account not only additions to a land use, but also subtractions. If all the gains to the cropland base are added over a decade and all the losses are subtracted, then the balance is net change. The U.S. Census of Agriculture shows total cropland every 4 or 5 years. The difference between 2 census years is a net figure since it implicitly accounts for both gains and losses.

Major Land Uses Shift

Major land uses had net gains or losses over the last several decades. For example, grassland pasture and range (excludes grazed forest land) decreased from 701 million acres in 1950 to 591 million acres by 1987, a net 16-percent decline.

Land in special uses increased from 118 to 279 million acres. Special uses include rural transportation, parks, wildlife areas, defense and industrial areas, and rural roads (Daugherty, 1991). Shifts occur to and from different uses of cropland, and to and from cropland to idle, from year to year, depending on such factors as Government programs to control excess production of surplus crops and programs to reduce soil erosion. These programs cause shifts in the amount of cropland idled or set aside in conservation reserve. Small shifts also occur in the amount of cropland used for pasture.

Much of the cropland converted to urban uses is consequently replaced by forest land and rangeland. These dynamic shifts in land use have been the reason that the total amount of cropland in the United States has remained relatively stable over the last 40 years.

Urban Conversions Are Nearly Always Permanent

Urban land uses are an exception to the dynamics exhibited by other land uses. Urban conversion is a one-way process. Once land is converted from some other use to an urban use, it tends to stay urban. Very little urban land is ever converted back to nonurban uses. Some conversion does take place within the urban category, however. For example, small amounts of residential land may eventually be converted to commercial or industrial uses.

Figure 4

Shifts in major land uses

Changes occur in major land uses over time due to economic stimulus. Once converted to urban uses, land seldom reverts to another use.

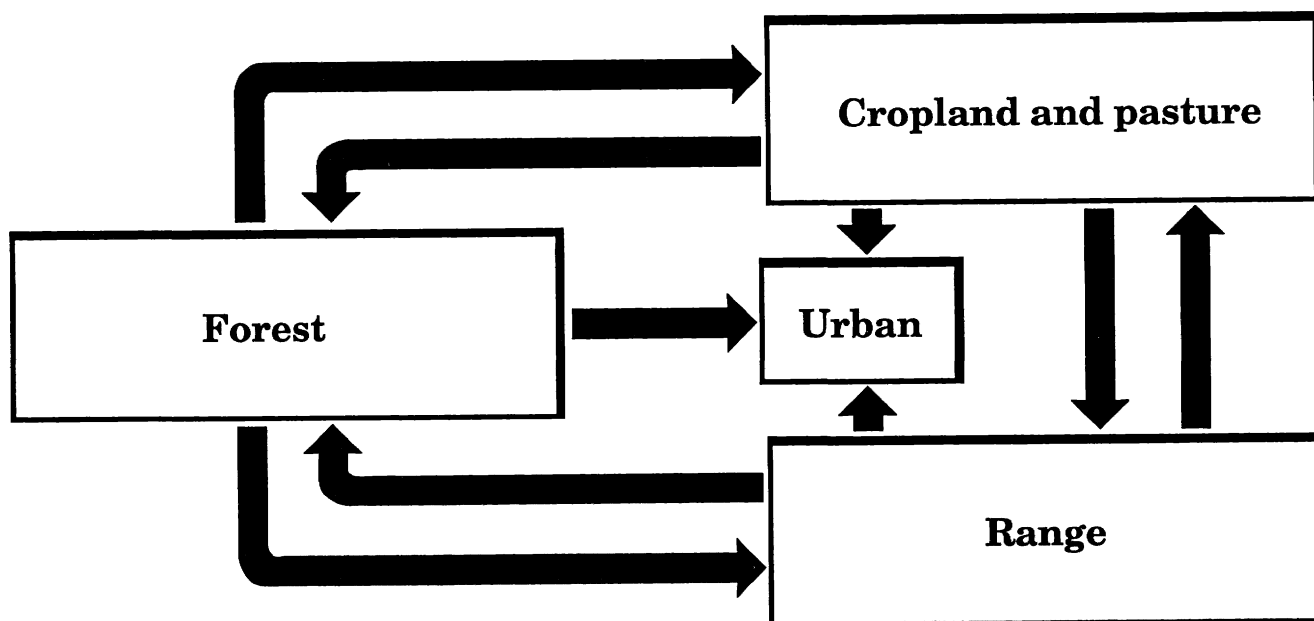
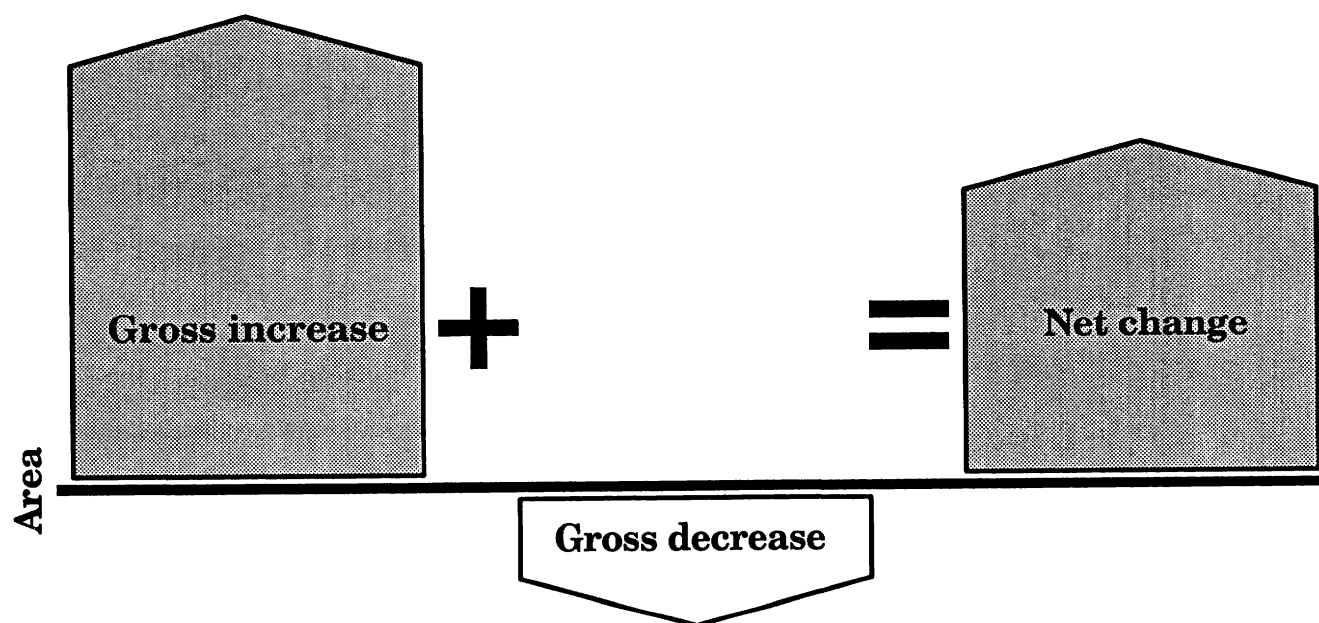


Figure 5

Gross and net land use change

Gross changes are total additions or subtractions to a land use. Net change takes into account not only additions to a land use, but also the subtractions.



Demographic Growth Spurs Losses of Cropland to Urban Uses

The amount of land urbanized is proportional to population growth and household formation.

One would intuitively expect population increase to correlate with the use of rural land for urban purposes. Dill and Otte (1970) found a correlation between population and urban land conversion in a study of land use change in the Western States.

$$Y = 123.64 + 0.035X_1 + 4.122X_2,$$

(0.003) (2.251)

where: Y = acres converted to residential use (annual average),

X_1 = number increase in population (annual average, 1950-60),

X_2 = percentage increase in population, 1950-60,

(Standard error of coefficients shown in parentheses),

$R^2 = 0.8$.

Urban and residential activities involve a greater intensity of land use and have a higher marginal value product of land that can outbid agriculture. Growing urban populations and commercial activities raise the demand for land at greater distances from the city's center and gradually expand onto what was formerly agricultural or forested land. While only a small part of total land area, these urban land expansions account for a large part of total urban land use change (Brooks, 1987).

The Rate of Urban Land Conversion Depends on the Phase of Development

Population growth in rapidly developing urban areas has characteristic phases or stages of

development (figs. 6 and 7). Population growth will generally be slow over the first phase, increase more rapidly, sometimes at an increasing rate, over the second phase, and then level off or decrease after reaching a peak in the third phase.

In the early stages of growth, residential land is relatively cheap, so consumers buy larger lots. More land for essential services, such as retail and office space, public buildings, and roads, must also be converted in newly growing areas.

Counties with smaller initial populations that add households at a faster rate are in an earlier stage of growth than are counties with larger populations that add households at a slower rate. Newly developing counties use more land per added household for larger residential lots and supporting urban land uses.

At later growth stages, land is more expensive and supporting land uses can better accommodate population increases, so less land is urbanized per added household.

There are several models that describe population growth (these apply to most populations, not just human populations), including the Gompertz model and the Pearl-Reed curve or logistic model (Catanese, 1972). For any particular population, the time period will vary during which each of the phases occurs. The exact shape of the curve may also vary, depending on the conditions that cause population to increase and decrease.

Figure 6

Growth in fast-growth counties

Population growth sets the stage for successive development and land use change.

Population

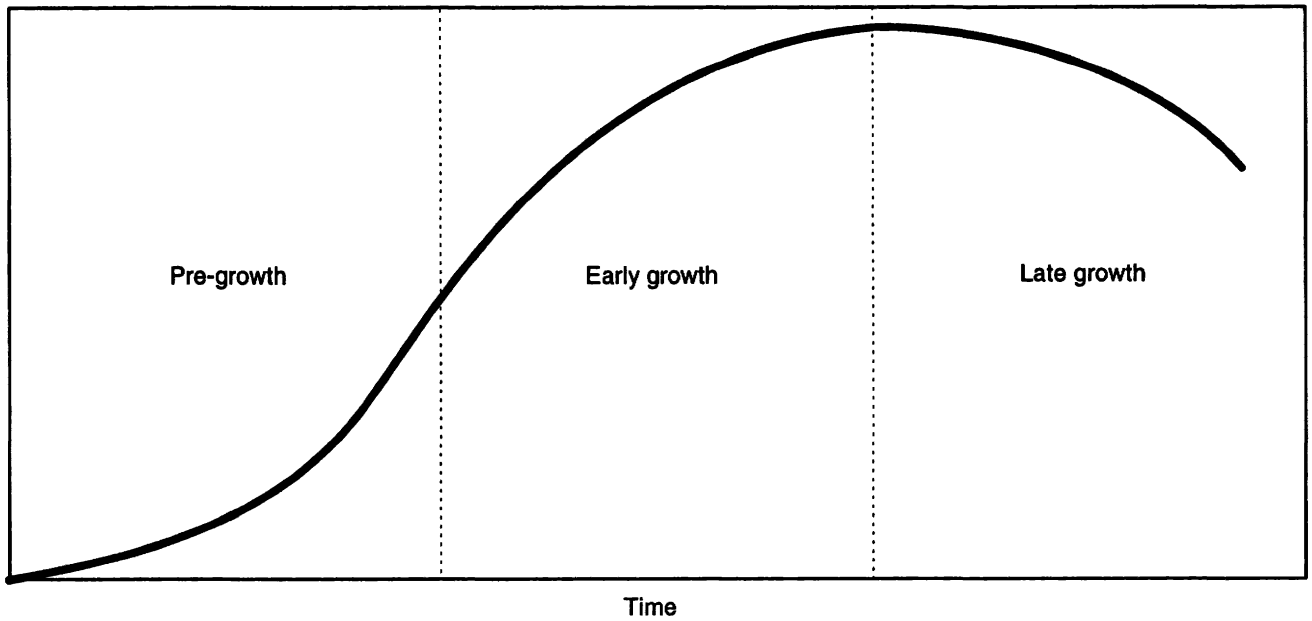
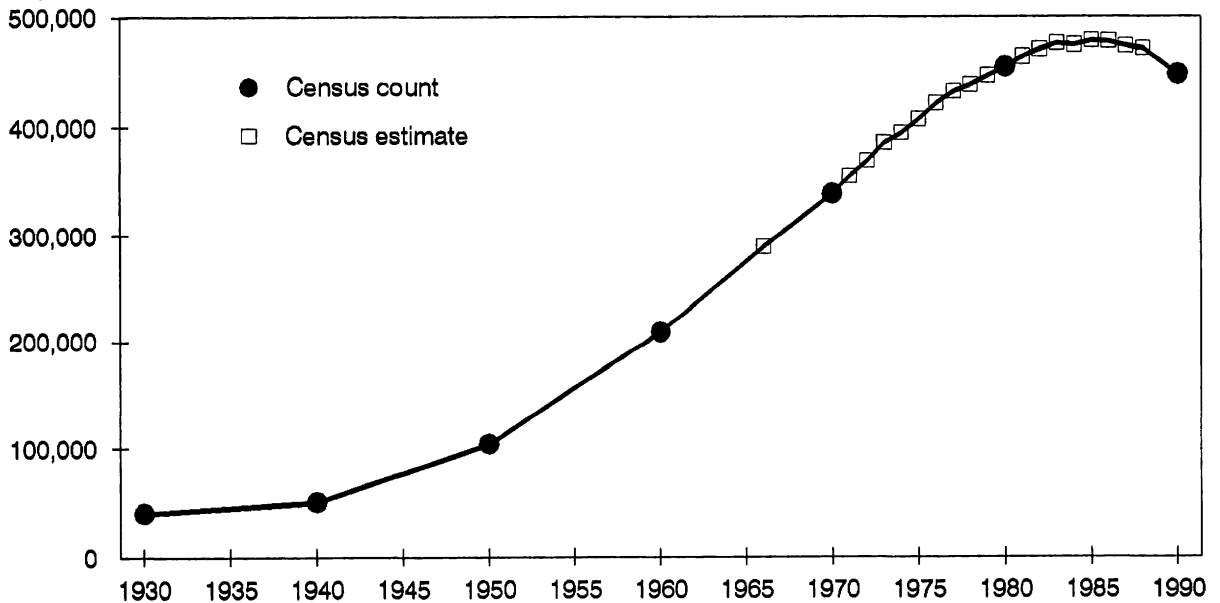


Figure 7

Population, Jefferson Parish, Louisiana

Population growth in Jefferson Parish, Louisiana exhibits characteristic phases of development; slow pre-growth, rapid early growth, then peaks and decreases.

Population



Sources: USDC, 1969, 1967, 1989c.

Household Growth Determines Urban Residential Land Use

The ratio of land use per household is a useful statistic in the study of urbanization because most decisions about living accommodations are made for household units.

Household Growth Provides Major Impetus for Land Use Change

Earlier ERS analyses of demographic and land use change in urbanizing areas considered only land consumption per capita (Anderson and Vesterby, 1990; Dill and Otte, 1970 and 1971; Frey, 1983; Zeimetz and others, 1976b). The ratio of residential land use change per household is a more useful relationship for analysis and projection because households make the decisions that affect the majority of land use. Population growth ultimately provides the major impetus for land use change and most urban conversions (60 to 75 percent) are for residential use, which are directly related to household formation and migration. In 1985, over 50 percent of households bought homes on lots under a fifth of an acre (table 2). This was down from a high of 57 percent in 1982, but up from the 1977 low of 44 percent. Only 12 percent of sales were for half-acre lots or larger in 1985 (USDC and HUD, 1986) (table 2).

Housing preference is related to life stage characteristics, such as age, marital status, and income, which are more easily understood in terms of household characteristics than by general population characteristics. Average household size decreased steadily from 3.37 persons per household in 1950 to 2.66 in 1987 (USDC, 1988). With smaller households at the same density, more land is needed per capita since more housing units must be built to serve the same number of people. For these reasons, it is more meaningful to analyze the ratio of land converted per household, rather than per capita, for comparison with earlier studies. The ratio of U.S. urban land used per household in 1980 was 0.6 acres per household.

This ratio is obtained by dividing 89 million households into 57 million acres of U.S. urban land (USDC, 1984; Daugherty, 1991). Urban land includes not only residential, but also roads, shopping centers, urban parks, recreation areas, and all other nonrural land. Even though urban uses include more than just residential, the average amount of land used by each household is still under 1 acre.

Table 2--Lot size of new single-family homes sold, 1985¹

Most new houses are built on small lots.

| Lot size per household | Acres per household | Share of households buying homes |
|-----------------------------------|---------------------|----------------------------------|
| | | Percent |
| Under 9,000 sq. ft. | 0.2 | 52 |
| 9,000-21,999 sq. ft. | .2-.5 | 36 |
| Over 22,000 sq. ft. | .5 | 12 |
| Median lot size: 8,875 sq. ft. | .2 | NA |

NA = Not applicable.

¹Residential uses include single-family homes and townhouses, multifamily houses, and mobile homes. Data reflect new single-family homes and townhouses sold in 1985. Sales of single-family homes (those reporting lot size) accounted for 26 percent of new privately owned housing units completed in 1985. Multifamily housing and mobile homes use even less land per housing unit than single-family homes.

Source: USDC and HUD, 1986.

Defining Fast-Growth Counties

This study focuses on the most rapidly growing counties at the rural-urban fringe where most land use change is expected to occur.

Definitions

The issue of land shifting to urban uses was examined by comparing the 135 fastest growing counties in the United States during the 1970's with the fast-growth counties of the 1960's (Freed and Jones, 1988; Vesterby, 1988c and 1987; Vesterby and Brooks, 1990; Zeimetz and others, 1976a, 1976b).

The 1970's Criteria

Fast-growth counties are defined as those with a population increase of at least 25,000 and 25 percent over a 10-year period. A total of 139 counties met the definition. Data were available for 135 counties, 5 percent of the U.S. total.

The 1960's Criteria

In the 1960's study, fast-growth counties were defined as those that grew by at least 20,000 and 30 percent over the decade. A total of 129 counties met the 1960's definition. Of those, data were available for 53 counties.

Comparison--1960's and 1970's

If the 1970's criteria had been used for the 1960's study, the same 129 counties would still have been in the study, plus six additional counties.

Our definition of fast-growth counties has two parts--a percentage and an absolute number. First, population increases greater than 25 percent eliminate populous counties that grew slowly from a large base. Second, population increases greater than 25,000 eliminate sparsely populated counties

that grew rapidly, but from a small base. Counties that met both parts of the definition are usually on the fringe of rural and urban areas, where population grows rapidly from moderate initial population bases. Using this definition, fast-growth counties will be those growing most rapidly and likely using a significant amount of rural land for urban purposes.

Stages of Growth

Fast-growth counties are captured in the middle or rising part of the stages-of-growth curve mentioned in the previous section. Fast-growth counties in one decade are not necessarily the same fast-growth counties in another decade. Seventy-one counties were fast-growth in both the 1960's and 1970's. One-half of the 1960's fast-growth counties had entered the slower, third stage of development by the 1970's and ceased to be fast-growth. From 1950 to 1990, only 29 counties in the United States were fast-growth every decade for four decades (Vesterby and Krupa, 1993). Different counties will be in the fast-growth category over time.

Urban Area Definition Compared With Census

The fast-growth estimate of urban area differs from that of the Bureau of the Census. In 1980, the estimate of urban area in the 135 fast-growth counties was 8.9 million acres. At the 95-percent probability level, the confidence interval is 8.4 to 9.3 million acres. Urban area in the same counties by the census definition was 9.4 million acres (USDC, 1981). The higher census number is partly due to census inclusion of some nonurban land.

Characteristics of Fast-Growth Counties

The 135 fast-growth counties accounted for less than 5 percent of over 3,000 U.S. counties, but over 47 percent of U.S. population growth in the 1970's.

Characteristics of Fast-Growth Counties

Fast-growth counties have several unique factors that distinguish them from rural counties. These factors include population, number of households, and metropolitan status. Population increase in fast-growth counties accounted for about one-half of the total U.S. population increase for the last four decades, from 1950 to 1990 (fig. 8).

Population

The 1970's fast-growth counties had a population of 24 million people in 1970 (table 3). By 1980, population had increased 45.6 percent to 35 million (15 percent of the United States). This increase was nearly one-half (47.5 percent) of the total population increase for the United States during the 1970's. Fifty-eight counties had a population increase of less than 45 percent. Twenty-one counties had a population increase of 85 percent or more. Sixty-three counties had a starting population base of between 100,000 and 500,000 people.

Households

The number of households in fast-growth counties increased more rapidly than population in the 1970's, from 7.5 to 12.5 million, a 68-percent increase (table 3). This was due largely to a decrease in the size of households during the decade, from 3.2 to 2.8 persons per household.

Households also increased more rapidly at the national level (25 percent) than did population (12 percent) (Sternlieb and others, 1982).

Metropolitan Counties

About one-fourth of all U.S. counties are included in census-defined Metropolitan Statistical Areas (MSA's). Fast-growth counties in MSA's numbered 118, nearly 90 percent of the study area (table 4).

For the first time since 1900, the U.S. population during the 1970's grew more rapidly in non-MSA counties than in MSA's. This phenomenon has been called the "rural renaissance" (Beale, 1975; Long and DeAre, 1983 and 1988). Population data for fast-growth counties confirm the trend of faster growth in non-MSA counties (56 percent) than in MSA counties (45 percent). Differences in household growth rates were even more pronounced, 79 percent for non-MSA's and 67 percent for MSA's.

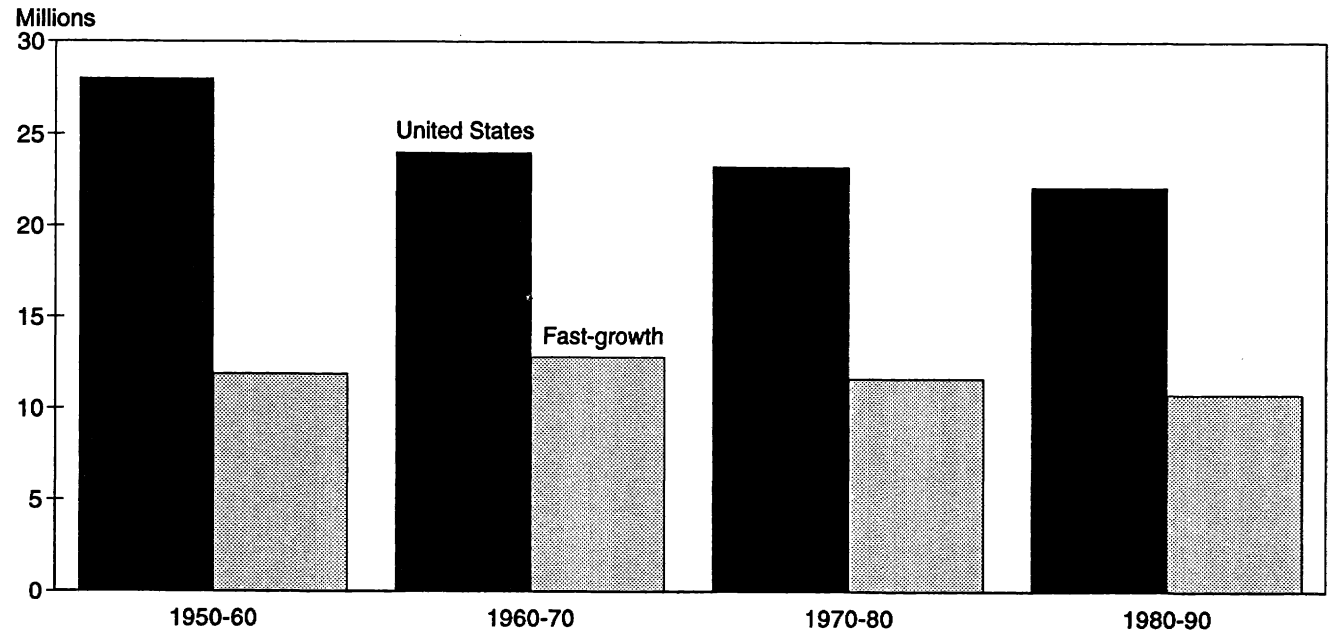
Location

Most fast-growth counties are at the rural-urban fringe, usually located near urban centers (fig. 9). Some counties include a central city, while others are metropolitan counties. About 70 percent are located in coastal States. Many are located in the Southeast and Southwest. None are located in the Central Plains.

Figure 8

Population increase by decade, United States and fast-growth counties, 1950-90¹

Population increase in fast-growth counties accounted for about one-half of the U.S. population increase from 1950 to 1960.



Sources: USDC, 1991, 1987, 1969. ¹ Fast-growth counties grew in population by at least 25,000 and 25 percent.

Table 3--Population and number of households, 1970-80

By 1980, population in fast-growth counties had increased 45.6 percent to 35 million. This increase was nearly one-half of the total population increase for the United States during the 1970's.

| Item | 1970 | 1980 | Increase, 1970-80 |
|---|---------|---------|-------------------|
| <i>Thousands</i> | | | |
| Population: | | | |
| United States | 203,302 | 226,546 | 23,244 |
| Fast-growth counties | 24,206 | 35,246 | 11,040 |
| <i>Percent</i> | | | |
| Fast-growth county share of population growth | 11.9 | 15.6 | 47.5 |
| <i>Thousands</i> | | | |
| Households: | | | |
| United States | 63,401 | 80,776 | 17,375 |
| Fast-growth counties | 7,488 | 12,547 | 5,059 |
| <i>Percent</i> | | | |
| Fast-growth county share of household growth | 11.8 | 15.5 | 29.1 |

Source: Heimlich, Vesterby, and Krupa, 1991.

Table 4--Demographic and land use change, by county characteristics, 1970's

U.S. population during the 1970's grew more rapidly in non-Metropolitan Statistical Areas (MSA's) than in MSA's, and more rapidly in counties with smaller initial base populations.

| Characteristic | Number of counties | Population | | Households | | Persons per household | | Increases, 1970-80 | |
|---|--------------------|-----------------------------|------|------------|------|-----------------------|------|----------------------|------------|
| | | 1970 | 1980 | 1970 | 1980 | 1970 | 1980 | Population | Households |
| | <i>Number</i> | <i>----- Millions -----</i> | | | | <i>Persons</i> | | <i>-- Percent --</i> | |
| Fast-growth ¹ counties | 135 | 24 | 35 | 7 | 13 | 3.2 | 2.8 | 46 | 68 |
| Metropolitan fast-growth counties: ^{2,3} | | | | | | | | | |
| SMSA counties | 83 | 20 | 29 | 6 | 10 | 3.3 | 2.8 | 43 | 65 |
| Non-SMSA | 52 | 4 | 6 | 1 | 2 | 3.1 | 2.7 | 57 | 78 |
| MSA counties | 118 | 23 | 34 | 7 | 12 | 3.2 | 2.8 | 45 | 67 |
| Non-MSA | 17 | 1 | 2 | 0 | 1 | 3.1 | 2.7 | 56 | 79 |
| 1970 population level: | | | | | | | | | |
| More than 500,000 | 7 | 7 | 10 | 2 | 4 | 3.1 | 2.7 | 40 | 60 |
| 100,000 to 500,000 | 63 | 13 | 18 | 4 | 6 | 3.3 | 2.8 | 42 | 65 |
| 50,000 to 100,000 | 47 | 4 | 6 | 1 | 2 | 3.3 | 2.9 | 61 | 83 |
| Less than 50,000 | 18 | 1 | 1 | 0 | 0 | 3.1 | 2.8 | 103 | 126 |
| Population change, 1970-80: | | | | | | | | | |
| Less than 35% | 29 | 8 | 10 | 2 | 4 | 3.3 | 2.9 | 31 | 51 |
| 35-45% | 29 | 8 | 11 | 2 | 4 | 3.2 | 2.8 | 39 | 60 |
| 45-55% | 25 | 3 | 4 | 1 | 2 | 3.2 | 2.8 | 51 | 72 |
| 55-65% | 17 | 3 | 5 | 1 | 2 | 3.2 | 2.8 | 59 | 84 |
| 65-75% | 9 | 1 | 2 | 0 | 1 | 3.1 | 2.7 | 69 | 92 |
| 75-85% | 5 | 0 | 1 | 0 | 0 | 3.3 | 2.8 | 81 | 14 |
| 85% or greater | 21 | 1 | 2 | 0 | 1 | 3.1 | 2.8 | 118 | 142 |

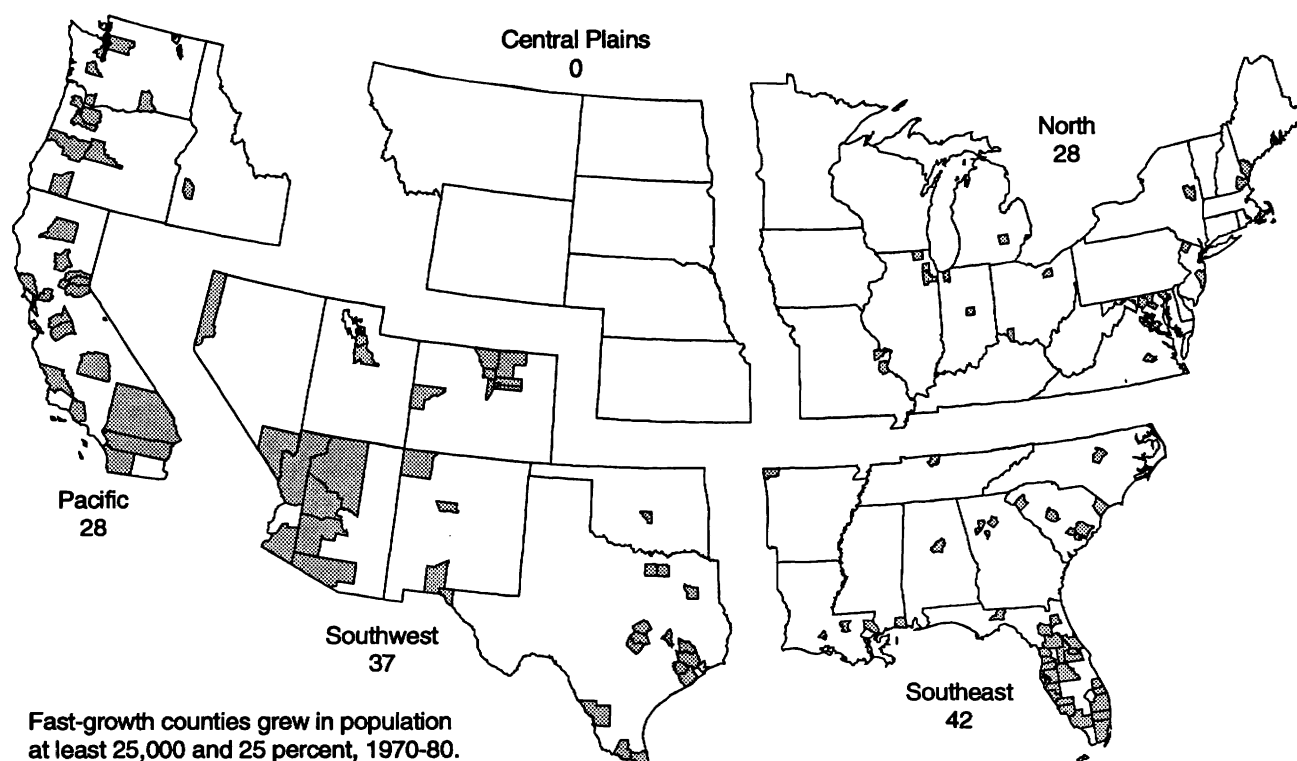
Zeros represent numbers less than 500,000. ¹Fast-growth counties had absolute population growth of at least 25,000 and at least a 25-percent increase. ²Standard Metropolitan Statistical Area (SMSA) is basically a group of counties containing a city of at least 50,000 persons (USDC, 1972). ³The requirement of a city was replaced by an "urbanized area" of at least 50,000, providing the metropolitan area was at least 100,000 (USDC, 1983).

Sources: Vesterby and Heimlich, 1991; Vesterby, USDC, 1983.

Figure 9

Fast-growth counties, 1980

*Seventy percent of fast-growth counties are located in coastal States.
None are in the Central Plains region.*



Sources: Heimlich and others, 1991; Vesterby, 1988c.

Constructing Land Use Transition Matrixes

Land use transition matrixes show the amount of land gained or lost from each use over time.

Constructing Land Use Transition Matrixes

Land use transition, or change, matrixes show the dynamics of change for each use from the early to the late periods. These matrixes tell the amount of land gained or lost from each use over time.

Uses at Early and Late Dates

Rows show land in each use from the early date (fig. 10). Columns show additions to each use by the late date. Column totals at the bottom show (a) ending, late date uses, and each row is totaled (b) to show beginning, early date, uses.

Diagonal Cells

The diagonal of a land use change matrix (d) shows the amount of land neither gained nor lost for each land use class during the study period.

Change Cells--Origin and Destination of Change

Land in a change matrix not on the diagonal (d) has changed use (c) during the period. Column entries show additions to a use during the decade. Row entries indicate the originating use of each change. Most uses both gain and lose land over a decade.

Figure 10

Generalized land use change matrix

Land use change matrixes show the dynamics of change for each use from early to late periods. These matrixes tell the amount of land gained or lost from each use over time.

| Land use | 1 | 2 | 3 | Early uses |
|-----------|---|---|---|------------|
| 1 | d | c | c | b |
| 2 | c | d | c | b |
| 3 | c | c | d | b |
| Late uses | a | a | a | Total |

Across a row, land is lost to other uses from the total (b) on the right side. Down a column, land is gained to the late date total (a) at the bottom. The diagonal (d) remains unchanged. Land that changed use is shown by (c), the elements off the diagonal.

ERS Used Paired-Point Sampling and Photo Interpretation

Studies on land use change for the 1960's and the 1970's detected actual changes in land use at the same points on aerial photographs taken at two different dates.

The 1960's and the 1970's ERS studies of land use change used similar techniques and procedures to identify, plot, and interpret sample points. Major differences in study methods are pointed out, as they occur, in the following sections. With those exceptions, the discussion of methods and procedures concentrates on the 1970's study. A detailed explanation of the 1960's study can be found in reports by Zeimetz and others (1976a, 1976b). Comparison of methods and procedures used in this and other studies is examined in depth by Vesterby (1988c).

Detecting Land Use Change

Land use change in fast-growth counties was obtained through the use of aerial photography and paired-point sampling.

Paired-Point Sampling

Paired-point, systematic, stratified, random sampling procedures were used in the 1970's study of land use change (discussed in more detail later). These procedures were based on standard spatial sampling methods and a modified Anderson (Anderson and others, 1976) land classification system (Vesterby, 1988c). Berry (1962), Cochran (1977), Frazier and Shovic (1980), Rosenfield (1982), and Tortora (1978) deal with spatial sampling methods in depth.

Sources of Aerial Photography

Photography for the 1970's study came from several different sources. These included the National Aeronautics and Space Administration (NASA); the Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS), U.S. Department of Agriculture (USDA); and the U.S. Geological Service (USGS). Earth Satellite Corporation interpreted land use from aerial photography for the beginning and end of the 1970's (Freed and Jones, 1988). In contrast, the 1960's ERS study of 53 fast-growth counties used ASCS photography, the only source available at that time that was compatible with

their study procedures (Zeimetz and others, 1976a).

Photography ranged from 1966 to 1976 for the early period and from 1980 to 1986 for the late period. The average year for early sample points was 1972 and 1982 for the late period. Over 16,000 photos were used, ranging in scale from 1:20,000 to 1:130,000 (Vesterby, 1988c).

Maps

Maps were used to plot sample points, identify Federal land, and delineate minor civil divisions and county civil divisions. Bureau of Land Management (BLM) Surface Management Status maps, available for most counties with 15 percent or more federally owned land, were used to identify Federal land ownership. Federal land was omitted under the assumption that little urbanization occurred in these areas. For counties where BLM maps were unavailable, USGS metric topographic maps or USGS county maps were used. All maps were at the 1:100,000 scale.

Transparent Dot-Grid Overlays

The U.S. Geological Survey constructed transparent dot-grid overlays, with sample points plotted at the same 1:100,000 scale as the maps. Sample points were randomly placed, one per grid cell, using a computer random plotting algorithm (Rosenfield, Fitzpatrick-Lins, and Johnson, 1987). The overlays were used to plot sample points on the topographic maps.

Plotting Sample Points

Study procedures enabled collection of data on 135 of 139 counties, for 97 percent coverage. In contrast, the 1960's ERS study was able to obtain photos for 53 of 129 counties, for 41 percent coverage.

Better quality and more complete photo coverage in the 1970's made it possible to get almost complete coverage. However, the need to accurately plot sample points on photos of widely

ranging scales would have limited data coverage without an accurate system for plotting sample points. Sample points must be accurately plotted, true to scale, on each early photo and plotted again at exactly the same point on the late date photo. Plotting accuracy was achieved by using true-to-scale, 1:100,000 BLM and USGS maps. First, sample points were transferred from dot-grid overlays to maps. Second, sample points were transferred from the maps to the first date of photography. Third, sample points were placed on the second date of photography. Photography could thus be used that differed greatly in scale.

Soil Quality

Soil quality data (soil mapping units) were recorded for each sample point that changed in use to or from cropland. Soil mapping units allowed the identification of soil types, prime/nonprime status, and land capability classifications. Using soil mapping units, soil surveys, and other data provided by the SCS, it was possible to estimate crop yields.

Geographic Coding

Geographic coding included the county Federal Information Processing Standards (FIPS) code for States and counties. Minor/county civil divisions

(MCD's and CCD's) were also identified. Geographic codes provide a means of linking land use data with socioeconomic data.

Land Use Categories

Land use was classified into 14 major uses (see box, "Land Use Classification Legend"). These include four urban uses, three agricultural uses, two rangeland uses, forest land, water, wetland, barren land, and land in transition. Land use classes were patterned after the hierarchical USGS or Anderson (Anderson and others, 1976) classification system. These classes provide an adequate breakdown of urban and other uses. More land use classes would have added to the cost of the study by requiring more sample points, and some uses would likely have been difficult to distinguish on aerial photography. Fewer classes would have meant a less complete analysis of land use change.

Several other noninterpreted classes were included to account for all sample points and all land area within each county. These included categories for Federal land, areas lacking photo coverage, points covered by clouds or snow, areas with water coverage over 40 acres, and Indian Reservations (Freed and Jones, 1988).

Land Use Classification Legend

1 Urban or Built-Up Land

- 11 Residential
Residential areas, including farmsteads
- 12 Commercial/Institutional/Industrial
Shopping centers, office complexes, commercial strips
- 14 Transportation/Communication/Utility
Highways, railroads, utilities, airports
- 16 Mixed Urban/Other Urban or Built-Up
Golf courses, urban parks, undeveloped land in urban setting

2 Agricultural Land

- 21 Crop and Pasture
All cropland, summer fallow, cover crops, planted grasses
- 22 Orchard/Grove/Vineyard/Nursery/Horticulture
Fruits, nuts, citrus, sod farms, tree nurseries, greenhouses
- 23 Confined Feeding Operations/Other Agriculture
Feedlots, horse training, machine sheds

3 Rangeland

- 30 Herbaceous Rangeland
Natural and potential vegetation is grasses and shrubs
- 31 Shrub and Brush Rangeland
In the East, includes "brushy pasture"

4 Forest Land

- Tree crown density of 10 percent or more, forested wetlands
- Undeveloped land in urban setting

5 Water

- Water bodies less than 40 acres and rivers less than 1/8 mile wide

6 Wetland

- Marshes, mud flats, wet meadows, bogs, seasonally flooded basins

7 Barren Land

- Sand dunes, dry salt flats, rock, strip mines, quarries, perennial snowfields

- 76 Land in Transition (sometimes included in Urban)
Land in process of being converted but no end use apparent
Cleared forest or cropland, drained wetland

Paired-Point More Reliable Than Proportional Sampling

A reliable, efficient procedure was used to obtain data on land use change.

Paired-Point Efficiency

Paired-point sampling shows, for each sample point, the beginning and ending land use, and the changes in use (Freed and Jones, 1988) (fig. 11). For a given level of accuracy, paired-point sampling requires fewer sample points than proportional sampling. Or, stated another way, paired-point sampling is more efficient than proportional sampling. The reason is that proportional sampling involves separate, independent, sample points for each date, while paired-point samples use the same sample points for each date, which effectively reduces the variance.

Designed to provide reliable land use change data, the study determined changes in land use for two dates at each sample point (Vesterby, 1988c). Some studies of land use provide a data set of the proportion of land in each major early date use and another independent data set for the late date. Such proportional sampling data only shows net changes in land use since there is no way of telling where each land use change originated.

Sample density was approximately one dot per 5,380 acres. Land use was interpreted at each sample point for each date and land use change determined by Earth Satellite Corporation (Freed and Jones, 1988). Fitzpatrick-Lins (1981, 1980) and Rosenfield and others (1987) used similar procedures to derive randomized spatial samples in analogous studies.

Population, households, and other socioeconomic data were obtained, by region and over time, to calculate rates of urban land conversion. Results of these analyses enabled an assessment of the impact of urban land conversion on agriculture. Fast-growth county results were combined with an estimate of the rate of urbanization for non-fast-growth counties to provide a national estimate of future U.S. urban land needs, assuming population continues to increase as projected by the Bureau of the Census.

Statistical Reliability of Results

Determination of sample size was critical to the success of the study. A sample size too small would provide insignificant results. A sample size too large would unnecessarily add to the cost. The objective was to choose a sample with a sufficient number of points to provide accurate and significant data for each of four regions.

Sample Size

Studies with a qualitative classification of observations, such as classes of land use where the observations must fall within one of two or more mutually exclusive categories, have a multinomial distribution (Rosenfield, 1982). The probability of a sample point falling into a particular class is

$$q_i, \quad i = 1, 2, \dots, k,$$

where k = number of classifications.

We determined sample size using (Mergerson, 1986; Rosenfield, 1982; Tortora, 1978):

$$n = \chi^2_{1, 1-\alpha/k} [q_i(1-q_i)]/\delta^2,$$

where: n = sample size

χ^2 = Chi square distribution with 1 degree of freedom,

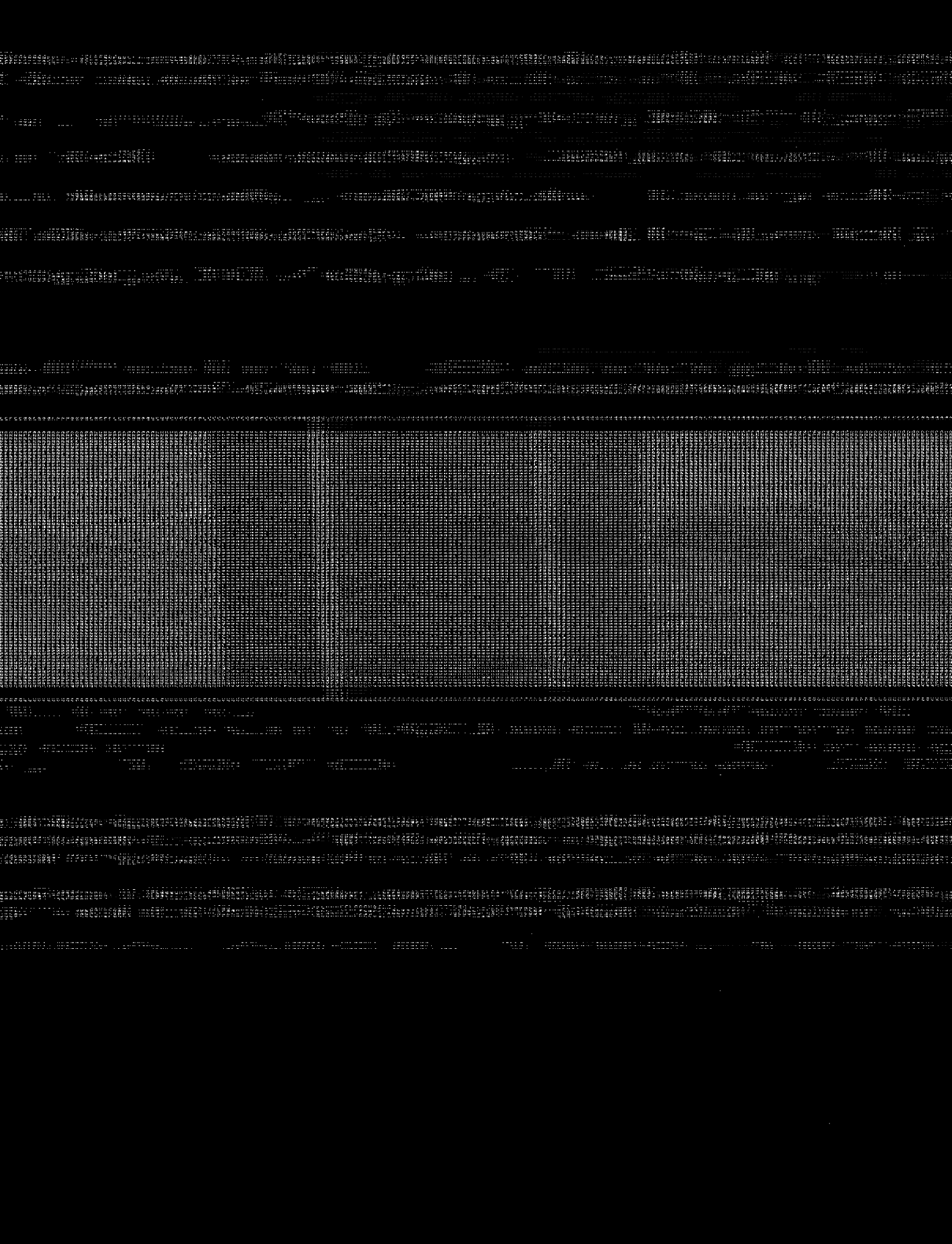
α = probability of exceeding the confidence interval,

q_i = proportion of observations in the i th class,

δ = percentage half width of the confidence interval.

Confidence Interval and Variance

Since change in land use is of primary interest, we wanted confidence intervals for the differences in use between early and late dates. These



Sample Points Were Plotted and Expanded to Land Area for Each County

After plotting and interpretation, the number of sample points were reduced to account for Federal land, Indian Reservations, large bodies of water, missing photography, cloud cover, and snow cover.

The objective of sampling land use was to obtain statistically significant information on changes in use between the early 1970's and the 1980's. Photo interpreters had to be able to discern land use for both early and late dates. Some sample points could not be interpreted for both dates, others were assumed to remain unchanged (Federal land and Indian Reservations), and others had to be discarded because they fell on large water bodies with inconsistent area measurements. Land use change data were collected for 135 fast-growth counties and another group of 57 counties with special cropland attributes for use in wetland and other analyses (table 5).

Fast-Growth Counties

After accounting for reductions in sample points for fast-growth counties, 15,129 points remained, representing 81 million acres.

Water Cover Excluded

There were 30,986 sample points in fast-growth counties. Of those, 614 water cover points were excluded. Water cover (water bodies over 40 acres in size and rivers greater than 1/8-mile wide) was not consistently available for all counties, especially those with large lakes, bays, and offshore islands and banks.

Sample Points Expanded to Land Area

Land area sample points (30,372, app. table 1) were expanded to land acreage in each county. The expansion weighting factor was obtained for each county by dividing total sample points into land area (USDC, 1981). The resulting acres per sample point were multiplied by the number of points interpreted for each use to determine acres of land by use. Acres by use were summed to provide national estimates (app. table 2).

Federal Land and Indian Reservations Excluded

Many of the fast-growth counties were located in Western States. Many of these were large

counties (some containing more land than several of the Eastern States) with sizable areas of Federal land and Indian Reservation land. San Bernardino County, California, for example, is 74 percent Federal land. The entire 135 fast-growth county study area was 47 percent Federal and Indian Reservation land. Assuming that Federal and Indian Reservation land does not change in use, 13,785 sample points were excluded from photo interpretation. Although Federal land and Indian land was not photo interpreted, those sample points (and all other sample points) were plotted on 1:100,000-scale Bureau of Land Management (BLM) and U.S. Geological Survey quadrangle maps that covered the entire 192-county area. The BLM maps delineated Federal land and Indian Reservations.

Missing Photography, Cloud Cover, and Snow Cover

Even though aerial photos came from several sources, complete coverage was not possible. Coverage was missing at the early date for 1,044 points. By the early 1980's, the National High Altitude Photography (NHAP) program had been flown over most of the country, improving the quantity (and quality) of photo coverage so that only 641 late date points had missing coverage.

Cloud cover obscured 97 early date points, but only one late date point. Snow cover obscured only seven sample points, all at the early date in Jefferson County, Colorado.

In most cases, missing photography, cloud cover, and snow cover affected only one date of a paired-point sample. If possible, land use was interpreted for the remaining date. Even one date was useful for some single date analyses where change was not a primary consideration. But for the study of the dynamics of land use change, all sample points for which land use could not be determined for both dates of a paired sample point were excluded. This left 15,129 sample points, or a 81,230,000-acre study area within the fast-growth counties (app. table 2).

Data Were Collected for Other Categories of Counties in Addition to Those That Were Fast-Growth

Sample points were plotted and interpreted for 57 other counties. These included 36 counties with large cropland losses during the 1970's, 20 with cropland gains and large population increases, and one that had large population increases for several consecutive decades. While these 57 additional

counties are not an integral part of the fast-growth county study, they are used later to help provide an estimate of the non-fast-growth county urban land conversion rate. The national distribution of households in these 57 counties was statistically similar to non-fast-growth counties.

In total, 39,662 sample points were plotted on maps for 192 counties.

Table 5--Sample points collected for 1970's dynamics of land use change studies

Land use change data were collected for 135 fast-growth counties and an additional 57 counties with special cropland attributes for use in wetland and other analyses.

| Database | Counties | Interpreted points | Federal land | IR,PC CC, WC points | Total points |
|---------------|---------------|--------------------|----------------------------------|---------------------------|--------------|
| | <i>Number</i> | | <i>----- Sample points -----</i> | | |
| Cropland gain | 20 | 2,324 | 382 | 421 | 3,127 |
| Cropland loss | 36 | 4,014 | 1,116 | 312 | 5,442 |
| Case study | 1 | 106 | 0 | 1 | 107 |
| Fast-growth | 135 | 15,129 | 11,745 | 4,112 | 30,986 |
| Total | 192 | 21,573 | 13,243 | 4,846 | 39,662 |

IR = Indian Reservations, PC = photo coverage missing, CC = cloud cover, WC = water cover (over 40 acres).
Source: Vesterby, 1988d.

From 740,000 to 1 Million Acres Were Estimated To Have Been Urbanized Annually in the United States in the 1970's

ERS estimates of annual urban conversion confirm the lower range of other estimates.

How Much Land Is Lost to Urban Uses Each Year?

The United States annually increased its urban area an estimated 740,000 to 1 million acres during the 1970's (table 6). This estimate has two parts. First, fast-growth counties increased at the rate of 240,000 acres per year during the 1970's (Vesterby and Brooks, 1988, 1990; app. table 2). Second, the 1970's estimate for non-fast-growth counties annually ranged from 500,000 to 760,000 acres.

The ERS estimate of annual urbanization is less than the estimate by the National Agricultural Lands Study of almost 3 million acres and less than the Bureau of the Census figure of 1.3 million acres (NALS, 1981; USDC, 1981, 1983) (table 7). The ERS estimate is comparable with the 1987 National Resources Inventory (USDA, 1989) observation of 726,000 acres for urban land and the second RCA estimate of about 900,000 acres (USDA, 1990c). The NALS study was based on data from the Conservation Needs Inventory (USDA, 1967), the 1975 Potential Cropland Study (Dideriksen and others, 1977), and the 1977 NRI (USDA, 1982). The NALS study has been criticized as providing estimates of urban conversion that are too high (Fischel, 1982; Brown and others, 1982; Lee, 1984; Platt, 1985; Raup, 1982; Simon and Sudman, 1982). Urban area estimates by the Bureau of the Census are based on mapping of population density and minor civil census division boundaries, rather than actual land use. These delineations are designed to differentiate between urban and rural population. These delineations include large areas that are not actually developed, such as cropland and forest land.

The estimates of urbanization may be cause for concern at State and local levels, especially in highly populated rural-urban fringe areas where open-space land for recreation, wildlife, environmental quality, and aesthetic enjoyment is scarce. However, from a national perspective, an annual urbanization rate of 1 million acres in a country containing 2.3 billion acres of land is a relatively small change.

Table 6--Average annual area urbanized, 1970-80

An estimated 740,000 to 1 million acres were urbanized each year during the 1970's.

| Item | Population increase | Household increase | Average annual increase in area |
|--------------------------|---------------------|--------------------|---------------------------------|
| - - Thousands - - | | | 1,000 acres |
| Fast-growth counties | 1,104 | 506 | 240 ¹ |
| Non-fast-growth counties | 1,220 | 1,231 | 500-760 ^{2,3} |
| United States | 2,324 | 1,737 | 740-1,000 |

¹Vesterby and Heimlich, 1991.

²The lower estimate is the product of the 1970's 1,231,000-household increase and 0.41 acres per capita, the 1960's non-SMSA land shift (Zeimet and others, 1976b; Dill and Otte, 1971).

³The higher estimate is derived by using the same 1970's 1,231,000-household increase times 0.62 acres per capita, the 1970's land shift of 57 non-fast-growth study counties (Vesterby, 1988d). These 57 counties had a frequency distribution not statistically different than that of all U.S. non-fast-growth counties from 1970 to 1980 ($\alpha = 0.01$) (Catanese, 1972; USDHHS, 1990).

Table 7--Estimated rates of urbanization, 1967-87

The national rate of conversion to urban uses is lower than other studies had previously estimated.

| Study | Period covered | Average annual | | |
|---|----------------|-------------------------------|-------------------------|----------------------------|
| | | Increase in household numbers | Expansion in urban area | Land conversion |
| | | <i>Thousands</i> | <i>1,000 acres</i> | <i>Acres per household</i> |
| Economic Research Service | 1970-80 | 1,738 | 740-1,000 | 0.43-0.58 |
| Bureau of the Census ¹ | 1970-80 | 1,738 | 1,276 | .73 |
| 1987 NRI ² | 1982-87 | 1,190 | 726 | .61 |
| Second Resources ³ Conservation Appraisal | 1977-82 | 1,880 | 900-1,100 | .48-.59 |
| National Agricultural ⁴ Lands Study | 1967-75 | 1,368 | 2,875 | 2.10 |

¹USDC, 1981,1983.

²USDA, 1989.

³USDA, 1990c. Based on comparison of 1977-82 (USDA, 1982) and Census Bureau urban area data.

⁴USDA, 1982. Based on 1967-75 Potential Cropland Study (Dideriksen and others, 1977).

Residential Component of Urban Land Increased the Most During the 1970's

All uses of urban land increased during the 1970's, but residential uses increased the most.

The residential component of urban land increased by 50 percent, more than any other urban land use category during the 1970's (fig. 12). The second largest increase (35 percent) was the commercial, institutional, and industrial category.

In fast-growth counties in the early 1970's, 6.5 million acres were in five urban use categories. By the early 1980's, urban uses had increased to 8.9 million acres, a 2.4-million-acre net increase, or 37 percent (app. table 2). Even though these were the fastest growing counties in the United States in the 1970's, the increase in urban land consumed only 1 percent of total land area in those counties. This happened because urban

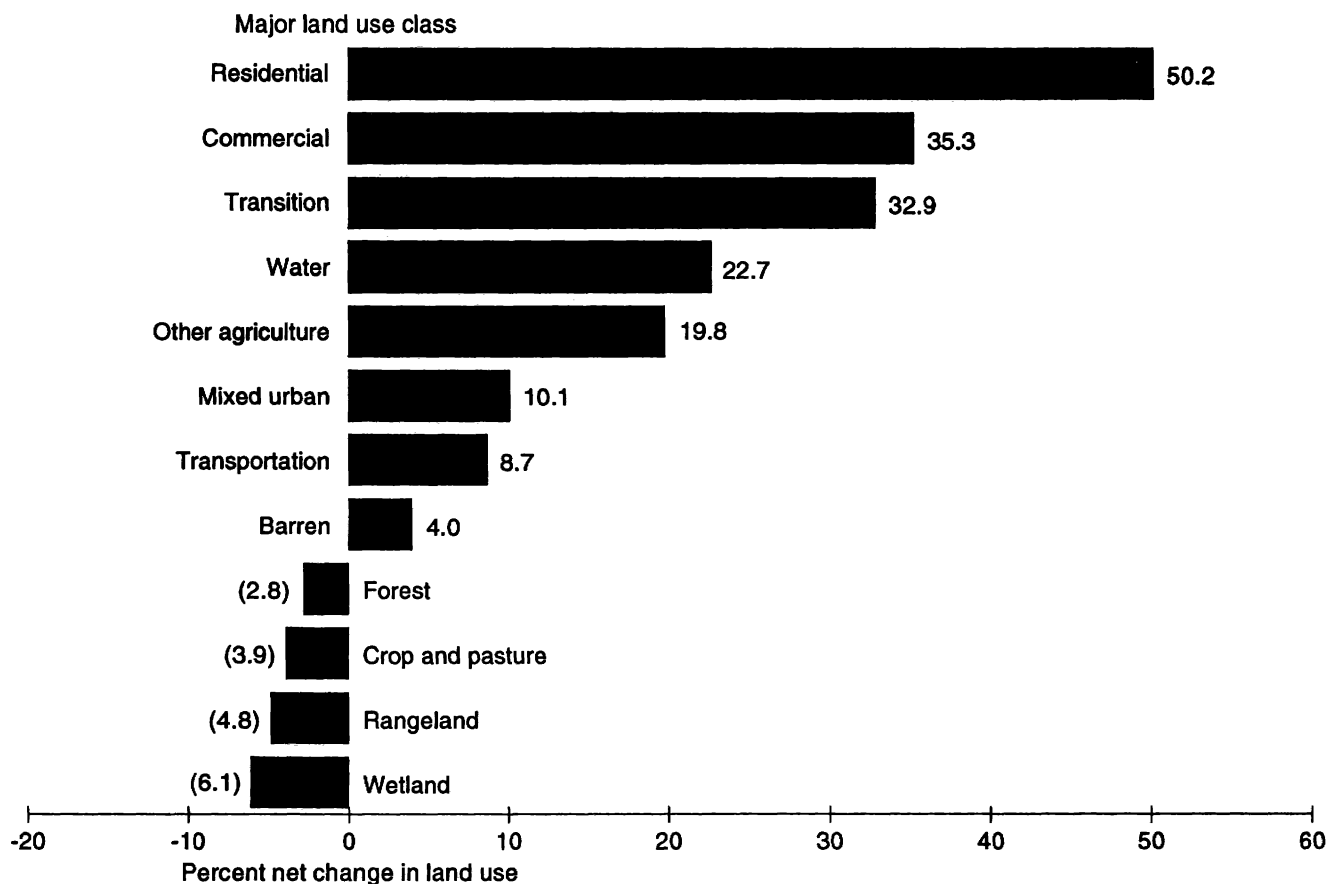
uses constituted only a small percent of the 1970 non-Federal land area in the fast-growth counties. Transportation and mixed urban uses increased the least of all urban uses, 9-10 percent.

The transition category is land that was in the process of being converted from one use to another, with the end use not apparent. Since most land in transition at the beginning of the decade was converted to urban by the end of the decade, and since transition was less than 0.5 percent of all land in the study, it was classified in the urban category. Transition land increased 33 percent in the 1970's.

Figure 12

Net changes in major land uses, 1970-80

The residential component of urban land increased by 50 percent, more than any other urban land use category during the 1970's.



Source: Heinrich and others, 1991.

While Urban Uses Had Large Increases, Cropland Decreased Relatively Little

Cropland and pasture were the prior uses of one-third of all new urban land. Even though percentage increases in urban land uses were large, relatively little came from cropland. The percentage change in cropland was small and was offset by gains from other uses.

About One-Third of New Urban Conversion Was From Cropland and Pasture

Of the 2.4 million acres of new urban area, 37 percent was from cropland and pasture. Forest land contributed 24 percent and rangeland 23 percent (fig. 13). Sixteen percent came from wetlands, water, land in transition, and other lands not used to produce crops. A study of urbanization of rural land in Canada from 1981 to 1986 found relationships similar to those in the United States. Approximately 30 percent of land converted to urban uses in Canada was being farmed and another 11 percent had been farmed in the past, but had been abandoned by 1981 (Warren, Kerr, and Turner, 1989).

Additions to Cropland and Pasture Offset Losses to Urban

While about one-third of the urban area expansion in the 1970's occurred on cropland and pasture, much of the cropland and pasture lost to urbanization was replaced by other land uses, such

as forest land and rangeland (fig. 14). A distinction must be made between gross and net changes. During the 1970's, 854,000 acres of cropland and pasture (includes orchards, ornamental, and all miscellaneous uses of agricultural land) were urbanized. This was a gross loss. However, rangeland, forest land, and other land uses replaced about one-third of the cropland and pasture that had converted to urban uses. Taking into account conversions to cropland and pasture, net loss was much less than gross loss.

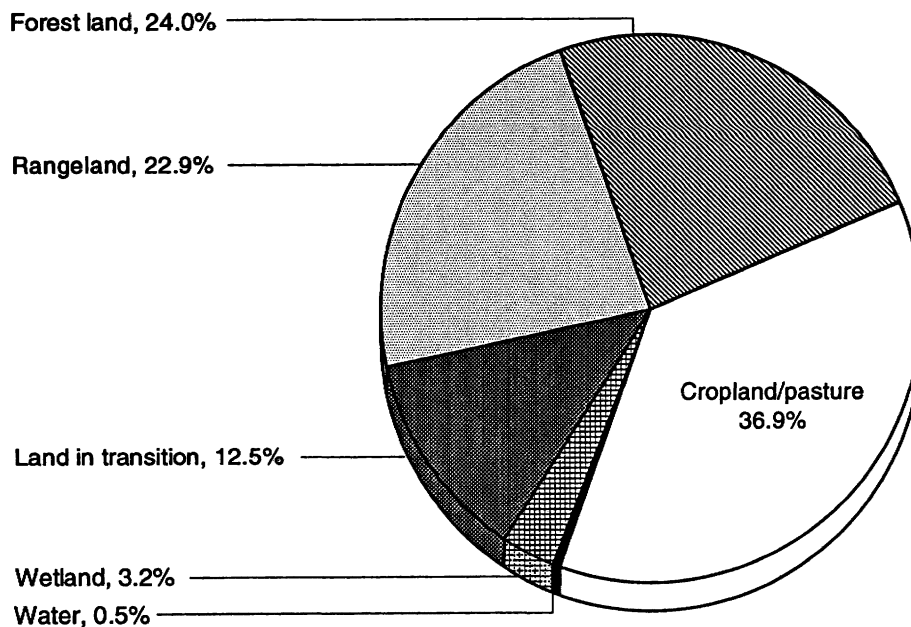
Cropland and Pasture Decreased Little

The decrease in cropland and pasture during the 1970's and 1960's was small, less than 4 percent (fig. 12). Cropland and pasture uses had a much larger beginning base acreage than urban uses. Thus, a large percentage increase in urban area accounts for a much smaller percentage loss of cropland and pasture. Forest and rangeland conversions to urban uses were also relatively small on a percentage basis.

Figure 13

Urbanized land, by prior land use, fast-growth counties, 1970-80

Cropland and pasture were the prior uses of one-third of all new urban land.

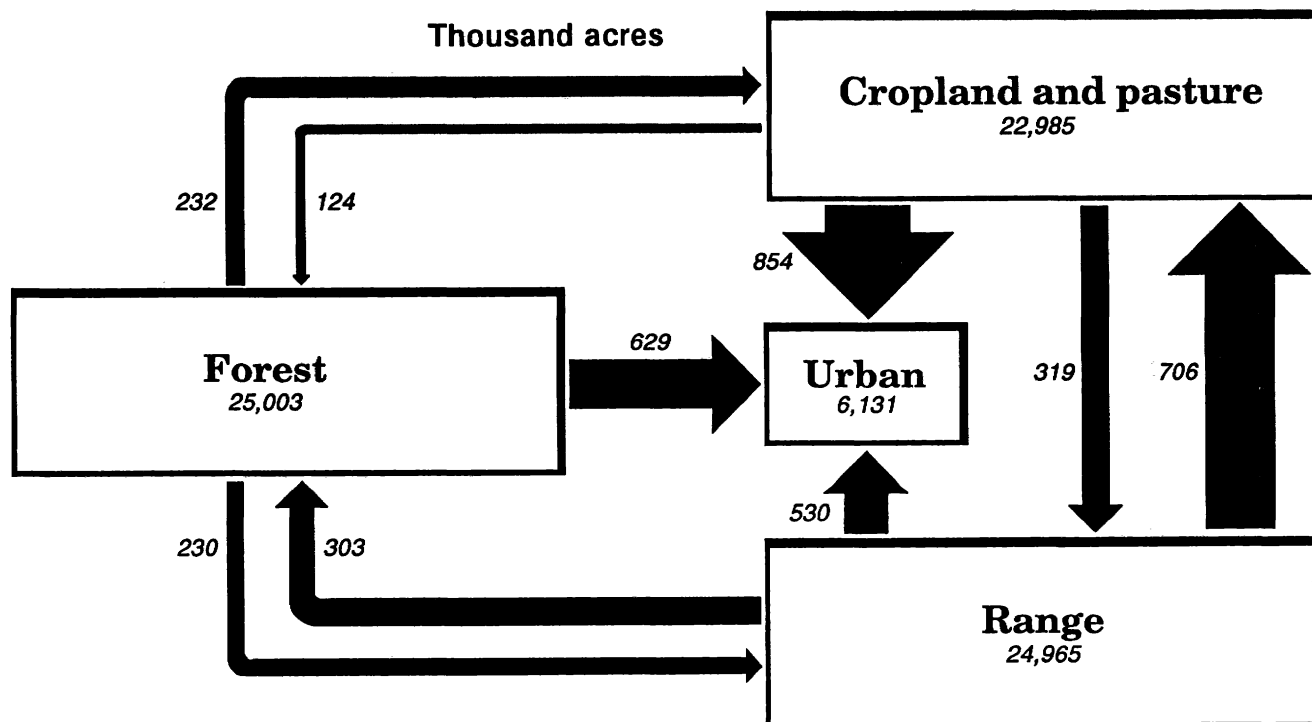


Source: App. table 2.

Figure 14

Shifts in major land uses, fast-growth counties, 1970-80^{1,2}

Much of the cropland and pasture lost to urbanization was replaced by other land uses, such as forest land and cropland.



¹Number in boxes are 1970; numbers along arrows are changes from 1970 to 1980.

²Minor uses are not shown. Cropland and pasture include feedlots, orchards, ornamentals, and other miscellaneous agricultural land. Forest includes wetland. Urban excludes land in transition.

Sources: Heimlich and others, 1991; USDA, 1990a.

Relatively Little Land Changes Use During a Decade

Most land uses change little, but losses to urban uses are chiefly permanent.

Most Land Remains in the Same Use

Land use is relatively stable, even in fast-growth counties, which have larger urban land use shifts than rural counties. In both the 1960's and 1970's, the proportion of land in each use category changed very little, as shown by the percentage of land remaining in each class throughout each decade on the diagonals of table 8. Residential land is particularly resistant to conversion to other uses. For both decades, 99 percent of land in residential use at the beginning of each decade was still residential at the end of the decade. A comparison of the 1960's and 1970's shows that cropland and pasture, forest land, and other land shifted more than residential uses, reflecting lower average values of land in the rural categories relative to residential use. However, even in most rural categories, 90 percent remained in the same use throughout the decade.

Urban Land Conversion Is Permanent

Of the net increase in urban uses, almost all was due to gross increases. Shifts out of the urban category totaled only 49,000 acres, less than 1 percent (app. table 2). Urban uses are an "absorbing state." That is, land shifts into but not out of urban uses. Thus, gross change and net change for urban uses are nearly the same. This is because urban uses have higher economic rents, which outbid rural uses. When shifts do occur in urban area, it is usually from one urban use to another (for example, from other urban built-up areas to residential). Tearing up parking lots or removing buildings to shift urban land back to cropland or other rural uses are not usually economical.

Table 8--Distribution of land use, fast-growth counties, 1960's and 1970's

During the 1960's and 1970's, 99 percent of land in residential use at the beginning of each decade was still residential at the end of the decade.

| Decade and land use | Residential | Commercial | Mixed urban | Cropland, pasture, and range | Forest | Other | Total |
|--|-------------|-------------|-------------|------------------------------|-------------|-------------|-------|
| <i>Percent of original use¹</i> | | | | | | | |
| 1960's: | | | | | | | |
| Residential | 99.6 | 0.1 | 0.1 | 0.1 | - | - | 100 |
| Commercial | - | 97.9 | - | 2.0 | - | .1 | 100 |
| Mixed urban | - | - | 100 | - | - | - | 100 |
| Cropland, pasture, and range | 2.8 | 1.1 | 1.0 | 92.7 | 2.2 | .2 | 100 |
| Forest | 2.2 | .5 | .6 | 1.7 | 94.9 | .1 | 100 |
| Other | 3.5 | 2.2 | .9 | 3.7 | .2 | 89.5 | 100 |
| 1970's: | | | | | | | |
| Residential | 99.1 | .3 | .3 | .3 | - | - | 100 |
| Commercial | - | 98.4 | .6 | 1.1 | - | - | 100 |
| Mixed urban | 14.3 | 2.9 | 79.8 | 2.2 | .3 | .6 | 100 |
| Cropland, pasture, and range | 2.1 | .5 | .9 | 95.0 | .9 | .5 | 100 |
| Forest | 2.0 | .2 | .8 | 1.8 | 94.8 | .4 | 100 |
| Other | .3 | .3 | - | 6.6 | 1.5 | 91.3 | 100 |

Numbers in bold = diagonal numbers. These numbers usually show little change.

- = No change.

¹Percent of land use that decreased or stayed in the same use (diagonal) for the 1960's and 1970's. The table shows the percentage of land that left each land use class during the decade. For example, in the 1970's, 1.8 percent of the land in forest uses at the beginning of the decade went into the cropland, pasture, and range category by the end of the decade.

Source: Zeimet and others (1976b), Vesterby and Brooks (1990), and app. table 2.

Urban Land Conversion Affects Prime Land No More Than Other Land

Fast-growth counties have a smaller proportion of prime cropland than the United States. Also, proportionately less prime cropland was converted to urban uses.

Prime Land in Fast-Growth Counties

Information on prime soils was obtained from the Soil Conservation Service (SCS) Soil Surveys. Soil Mapping Units provide a link to determine the quality of land urbanized. Prime land is the focus of the Federal Farmland Protection Policy Act, and thus, it is important to know where prime lands are and how urbanization affects these areas. Prime land is defined by USDA as the following:

... best suited to producing food and fiber
... and ... has the soil quality, growing season and moisture supply needed to produce sustained high yields of crops economically when treated and managed
... according to modern farming methods (USDA, 1975).

Fast-growth county boundaries and prime cropland are shown in figure 15. Prime cropland is shown by dots where each dot represents 50,000 acres. Fast-growth counties tended not to be concentrated on prime lands. Many are located in Florida and Arizona, States that have very little prime land. Few fast-growth counties are in the North Central States, the Mississippi River regions, or the Red River Valley region, all of which had heavy concentrations of prime land.

Fast-growth counties have proportionately less prime agricultural land (43 percent) than the United States (49 percent) (fig. 16). Many were in Florida where there is little prime farmland. Others in California were not prime because the soils found there, although well suited to certain kinds of highly productive agriculture, do not have the physical attributes required for elevation to prime land status. In the urbanizing parts of the Southeast and Southwest, many soils are classified as prime only if they are drained or irrigated.

A misperception exists that prime land, and therefore, urbanization of prime land, is in greater

proportion in rapidly urbanizing areas. The misperception has been stated as follows.

The land most likely to be converted to non-agricultural uses is prime farmland Most U.S. cities and larger rural towns, therefore, are surrounded by productive agricultural land and any expansion must occur on such land (USDA, 1990c).

In a study of prime agricultural land, Dillman and Cousins (1982) concluded that Standard Metropolitan Statistical Areas (SMSA's) accounted for a disproportionately large share of the Nation's prime land. Their research led to evidence that proportionately more prime land tended to be developed. However, their study was based on only one SMSA. Neither the fast-growth study (Heimlich, Vesterby, and Krupa, 1991; Heimlich and Vesterby, 1992) nor the study by Dillman and Cousins provide conclusive evidence of the rate of prime land urbanization. While the fast-growth study accounted for nearly one-half of the U.S. 1970's population growth, which should be indicative of a major portion of urban expansion, it did not account for all U.S. urbanization.

Urbanization on Prime Land

Of all the cropland and pasture in fast-growth counties, 43 percent was prime. But, of all cropland and pasture urbanized during the 1970's, only 40 percent was prime (fig. 17). Prime cropland and pasture were urbanized at a rate slightly less than its occurrence.

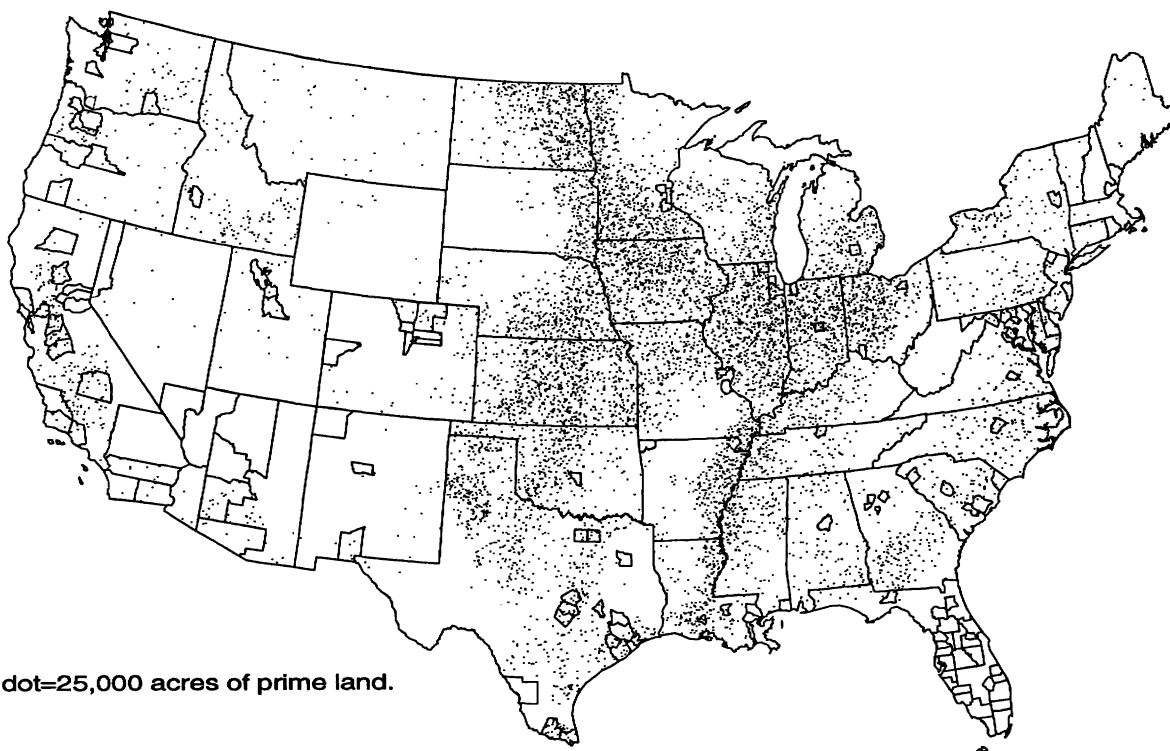
Net Losses on Prime Cropland Were Small

Losses of prime cropland and pasture to urban uses are only part of the picture. The picture is not complete until gains to prime cropland and pasture are considered. Gains of prime cropland and pasture converted from other rural uses replaced one-third of the prime cropland lost to urban uses (fig. 18).

Figure 15

Prime cropland and fast-growth counties, 1982

Fast-growth counties tended not to concentrate on prime lands. Many are located in Florida and Arizona, States that have very little prime land.



1 dot=25,000 acres of prime land.

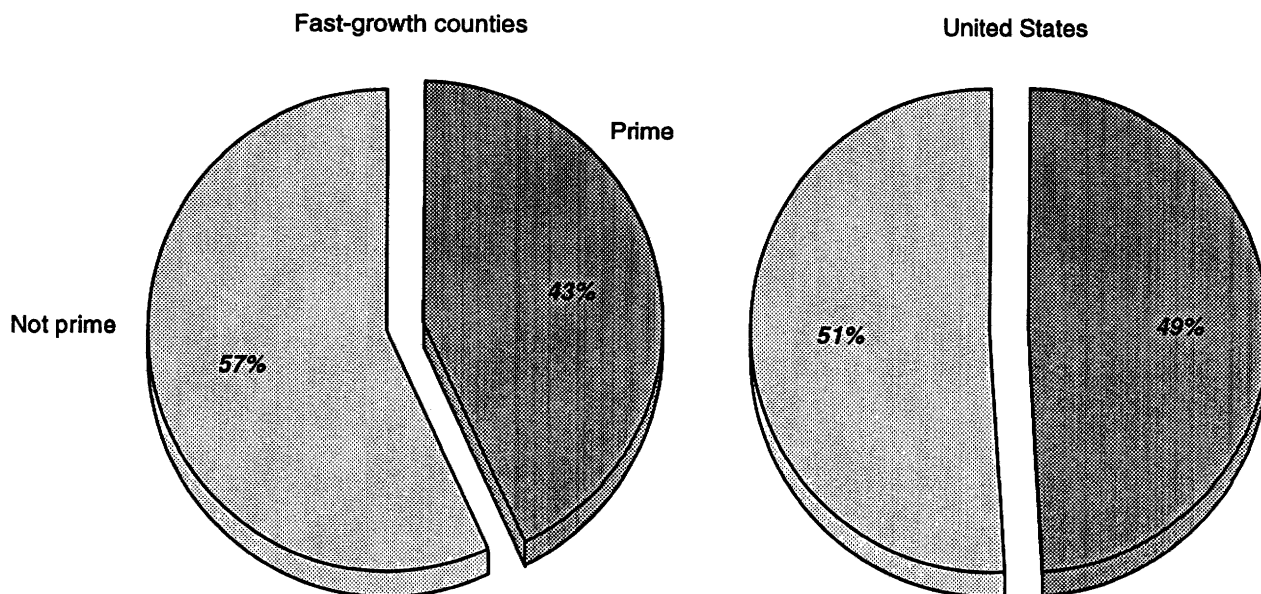
County boundaries shown for each of 135 fast-growth counties. Study included 48 contiguous States.

Source: 1982 National Resources Inventory (USDA, 1987).

Figure 16

Quality of cropland and pasture, fast-growth counties and United States, 1982

Only 43 percent of cropland and pasture in fast-growth counties is considered prime land, compared with almost half of total U.S. cropland and pasture.

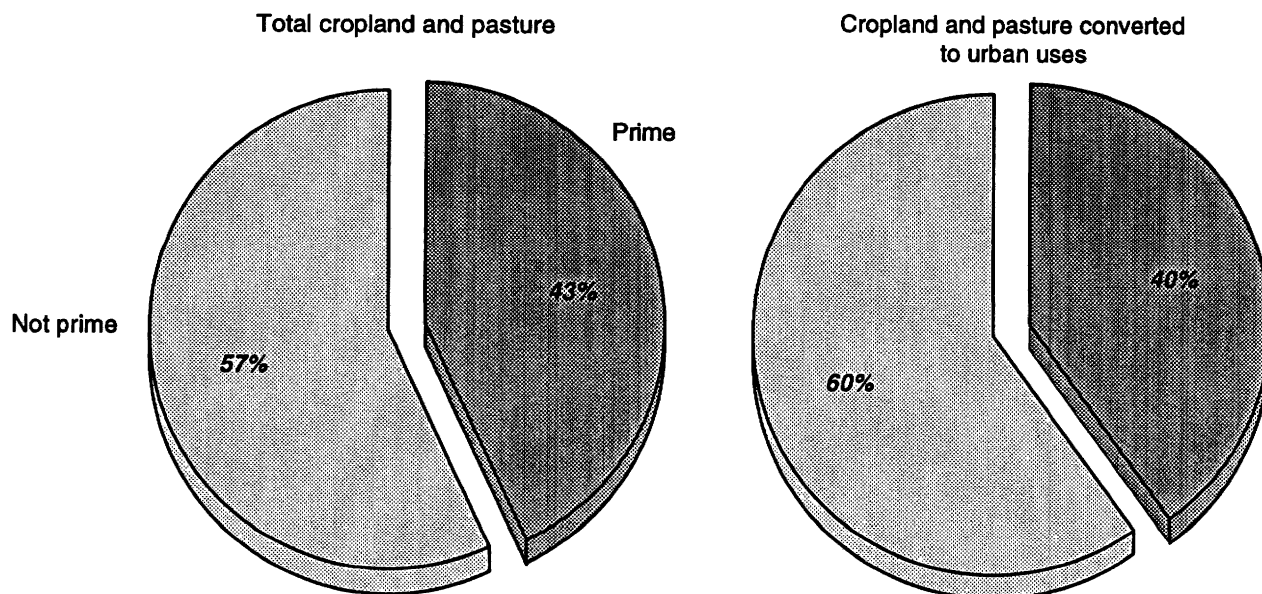


Sources: USDA, 1987; Vesterby, 1988d.

Figure 17

Quality of cropland and pasture, fast-growth counties, 1970-80

Prime cropland and pasture were urbanized at a rate slightly less than its occurrence. While 43 percent of cropland and pasture in fast-growth counties was prime, 40 percent of the cropland and pasture converted to urban uses was prime.

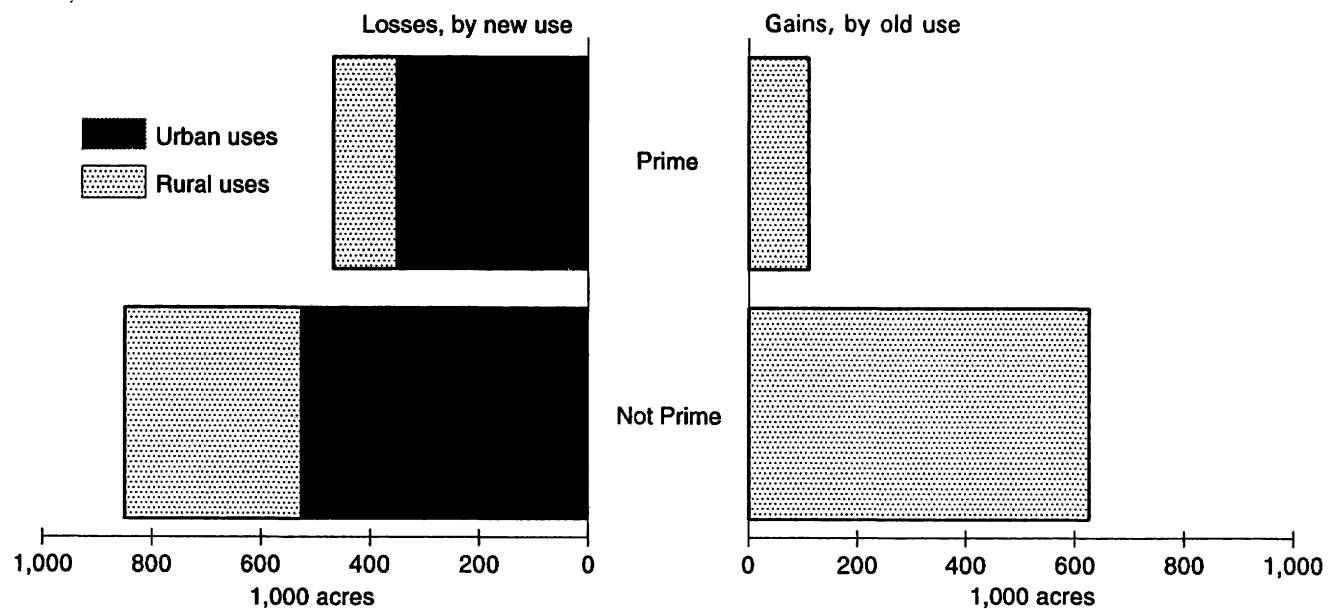


Sources: USDA, 1987; Vesterby, 1988d.

Figure 18

Conversion of cropland and pasture, fast-growth counties, 1979-80

Gains of prime cropland and pasture converted from other rural uses replaced one-third of the prime cropland lost to urban uses.



The Rate of Urban Land Conversion Remained the Same Since the 1960's

Both U.S. population and the amount of urban land increased in the 1960's and 1970's, but the marginal rate of urban land conversion per household remained constant.

An important reason for studying urbanization of agricultural land is to find out rates of conversion--how many acres are converted per decade. The rates of past conversion provide a basis for estimating future conversion, and ultimately, to determine constraints on the Nation's capacity to produce food and fiber. To do this, not only is it useful to know the rates of conversion, but also if the rates are changing over time. These rates are expressed as acres converted per household since the household unit determines the amount of residential land urbanized (Vesterby and Heimlich, 1991). Useful information is gained by looking at marginal rates of conversion, as well as absolute and average rates.

Population and Household Growth

To understand rates of urban land conversion, it is necessary to know trends of the number of households, since rates of land conversion are expressed in acres per household.

Number of Households Increased More Rapidly Than Population

Both population and households increased during the 1960's and 1970's in fast-growth counties (table 9). But households increased more rapidly than population. While population increased 46 percent in both the 1960's and 1970's, households increased more, 55 and 68 percent, respectively. The reason that households increased more rapidly than population is simple: average household size decreased significantly from 1960 to 1970.

Household Size

The marginal (increase in households divided by increase in population) household size fell from 3.06 to 2.18 persons per household from the 1960's to the 1970's. Decreased marginal household size resulted in reduced average household size. Average household size dropped 5 and 13 percent in the 1960's and 1970's, respectively.

Rates of Urban Land Conversion

Marginal and average rates of land conversion provide a means of comparison of urbanization between time periods.

Marginal Rates of Conversion

We define the "marginal rate of urban land conversion" as the increase in urban land divided by the increase in households over a decade. This is a measure of land conversion by households added during the period. While some new household formation developed on land that was already urban, the amount is likely to be small for two reasons. First, the definition of fast-growth counties (population increase of 25,000 and 25 percent) avoids densely populated core areas and concentrates on rapidly growing rural-urban fringe counties. Second, many central city core areas grew little during the 1970's; some declined in population.

Marginal urban land conversion was nearly unchanged at 0.46 and 0.47 acres per household for both the 1960's and 1970's (table 9). Since households increased proportionately more than population, marginal land use per capita increased from 0.15 acres per person in the 1960's to 0.22 in the 1970's (Vesterby and Brooks, 1990). This was a result of smaller average household size in the 1970's compared with the 1960's.

Average Land Use Per Household

On average, households used 0.87 acre of urban land in fast-growth counties in the 1970's. By 1980, the average consumption decreased to 0.71 acre as growth occurred and developed densities increased. With marginal urban land consumption lower than average consumption in both the 1960's and 1970's, average rates could only go down by the end of each decade. These findings are supported by other research (Peiser, 1989). Greater change in household structure, reflected in smaller average household size, accompanied growth during the 1960's and 1970's.

Composition of Fast-Growth Counties

Even though not all fast-growth counties are the same from one decade to the next, it is useful to compare the groups of counties that meet the fast-growth definition in different decades. Only 71 counties were fast-growth in both the 1960's and 1970's. One-half of the fast-growth counties had dropped out of the fast-growth classification as they entered later stages of growth in the 1970's. But the marginal and average rates of urban land conversion in fast-growth counties are similar because the fast-growth definition captures counties at the same earlier growth stage. For the 1960's and 1970's, the average and marginal rates of urban land conversion were almost the same, even through the composition of fast-growth counties changed (table 9). Thus, by using urban land conversion rates from previous decades together with population or household estimates for current or future decades, one can estimate acres of future land conversion.

Residential and Nonresidential Urban Land Conversion

Urban land conversion is broken down into two major categories, residential and nonresidential. Residential includes houses, apartment buildings, and other places where people live. Nonresidential includes shopping centers, transportation systems, utilities, commercial and industrial facilities, and other infrastructure that service residential uses.

The relationship between residential and nonresidential is important because it shows the amount of land used to service residential categories.

Residential marginal land use increased 37 percent from the 1960's to the 1970's (0.27 to 0.37 acres per household). At the same time, nonresidential marginal land use decreased 44 percent (0.18 to 0.10 acres per household). Thus, while the residential component of urban land increased from 60 to 79 percent, the nonresidential component decreased from 40 to 21 percent. In other words, in the 1960's, it took 0.67 acre of nonresidential land to service each acre of residential land. In the 1970's, it only took 0.27 acre.

Residential and nonresidential marginal land uses offset each other in the 1960's and 1970's, resulting in a constant overall urban land consumption rate of 0.46 acres per household. While constant for two decades, the marginal rate could change in coming decades. First, the number of persons per household is not likely to get much lower than 2.18 persons. Second, the nonresidential component of urban land may not continue to decrease. It is already down to 0.1 acre per household, almost one-half of the 1960's rate. If either of these rates were to increase, then the future urban consumption rate would likely increase.

Table 9--Demographic and land use change, fast-growth counties, 1960's to 1980's

The number of households increased more rapidly than population during the 1960's and 1970's in fast-growth counties.

| Year and category | Population | Households | Persons per household | Urban land in fast-growth counties | | | | | |
|----------------------------------|---------------|------------|-----------------------|------------------------------------|---------------|-------------|---------------|----------------|---------------|
| | | | | All urban | | Residential | | Nonresidential | |
| | | | | Total | Per household | Total | Per household | Total | Per household |
| | -- Million -- | | Number | 1,000 acres | Acres | 1,000 acres | Acres | 1,000 acres | Acres |
| 1960's study:¹ | | | | | | | | | |
| 1960 | 11.1 | 3.1 | -- | 2,748 | -- | 1,454 | -- | 1,294 | -- |
| 1970 | 16.3 | 4.8 | -- | 3,523 | -- | 1,918 | -- | 1,605 | -- |
| Difference | 5.2 | 1.7 | -- | 775 | -- | 464 | -- | 311 | -- |
| Average: | | | | | | | | | |
| 1960 | -- | -- | 3.54 | -- | 0.87 | -- | .46 | -- | .41 |
| 1970 | -- | -- | 3.37 | -- | .73 | -- | .40 | -- | .33 |
| Marginal ² | -- | -- | 3.06 | -- | .46 | -- | .27 | -- | .18 |
| 1970's study:³ | | | | | | | | | |
| 1970 | 24.2 | 7.5 | -- | 6,485 | -- | 3,854 | -- | 2,631 | -- |
| 1980 | 35.2 | 12.5 | -- | 8,865 | -- | 5,728 | -- | 3,136 | -- |
| Difference | 11.0 | 5.1 | -- | 2,380 | -- | 1,874 | -- | 505 | -- |
| Average: | | | | | | | | | |
| 1970 | -- | -- | 3.23 | -- | .87 | -- | .51 | -- | .35 |
| 1980 | -- | -- | 2.81 | -- | .71 | -- | .46 | -- | .25 |
| Marginal ² | -- | -- | 2.18 | -- | .47 | -- | .37 | -- | .10 |

-- = Not applicable. ¹Fifty-three counties with a population gain of greater than 20,000 and at least a 30-percent increase between 1960 and 1970 (Zeimet and others, 1976b). ²Net change in urban land divided by the change in household numbers. ³Vesterby and Heimlich, 1991.

Most New Urban Area Was Added in Metro Counties, But Rural Counties Consumed Land at Higher Rates Than Metro

Metro counties converted land to urban uses at a rate of 0.46 acre per household for 4.8 million households. Rural counties had a much higher conversion rate, 0.95 acre, but for only 5 percent as many households.

Metropolitan counties converted land to urban uses at nearly one-half the rate of rural counties (table 10). From 1970 to 1980, the conversion of land to urban uses was 0.46 acre per household for MSA fast-growth counties. Metro counties converted more land to urban uses because they added more households than did rural counties. In rural counties, the conversion rate was 0.95 acre per household. The non-MSA rate is based on a relatively small area and small household change (234,000 acres and 247,390 households) compared with metro counties (2.2 million acres and 4.8 million households). A similar relationship held for the older SMSA definition of counties, although it was not as pronounced because there were fewer SMSA fast-growth counties.

The decade of the 1970's was the first time since 1900 that rural population growth exceeded metropolitan growth. This "rural renaissance" phenomenon represented a reversal of many decades of rural population movement to the cities (Beale, 1975; Long and DeAre, 1983, 1988). The

reversal was probably caused by a decentralization of manufacturing and other industry, increased settlement of retired people, expansion of State colleges, more recreation activity, and apparent higher birthrates in nonmetro areas (Beale, 1975).

The fast-growth counties were divided into Standard Metropolitan Statistical Areas (SMSA's). Both SMSA's and redefined Metropolitan Statistical Areas (MSA's) were analyzed (USDC, 1986). Fast-growth study data confirmed the trend of faster population growth in rural fast-growth counties (57 percent) compared with metropolitan counties (43 percent). Households grew even more rapidly (78 percent) than population (65 percent). The relationship was similar for metropolitan areas defined by either the SMSA or MSA criteria. The "rural renaissance" may be over since new evidence seems to suggest that early 1980's metropolitan growth rates are again exceeding rural rates (Long and DeAre, 1988).

Table 10--Metro and rural growth, fast-growth counties, 1970-80

From 1970 to 1980, metropolitan counties converted land to urban uses at nearly one-half the rate of rural counties. But metro counties converted more land to urban uses because they added more households than did rural counties.

| Year and county type | Number of counties | Growth in-- | | Gross land conversion |
|-------------------------|-----------------------|------------------|------------------------|--------------------------------|
| | | Households | Urban area | |
| | <i>Number</i> | <i>Thousands</i> | <i>1,000 acres</i> | <i>Acres per household</i> |
| 1970 definition: | | | | |
| SMSA | 83 | 4,043 | 1,732 | 0.43 |
| Rural | 52 | 1,016 | 729 | .72 |
| 1980 definition: | | | | |
| MSA counties | 118 | 4,812 | 2,227 | .46 |
| Rural | 17 | 247 | 234 | .95 |

SMSA = Standard Metropolitan Statistical Area.

MSA = Metropolitan Statistical Area.

Source: Vesterby and Heimlich, 1991.

Counties in Earlier Growth Stages Converted More Land to Urban Uses Per New Household

While counties continue to convert land to urban uses as they grow in population, they use less land per household.

The Most Rapidly Growing Counties Convert More Land Per Household

Counties with the most rapid increase in population used the most land per new household. Counties that grew faster than 100 percent in population added as much as 1.18 acres per household to urban area, while those that grew less than 50 percent added about one-third to one-half acre (fig. 19). Demographic growth and urban land conversion is affected by residential land supply and demand and by differing needs for nonresidential infrastructure, such as shopping centers, roads, hospitals, and schools. Counties with rapid increases in population and with low initial population bases are in earlier stages of growth when land is less expensive and more land is used per household. Counties in later stages of growth have slower growth rates, higher population bases, and more expensive land, and they use less land per household.

Counties With Smaller Population Bases Convert More Land Per Household

Urban conversion per household is inversely proportional to initial population level. The least

populated counties grew 60 percent faster than the most populous counties and converted almost three times as much land per change in household. Land consumption was more than an acre for each new household in smaller counties, but only one-third acre per household in counties with more than 500,000 people.

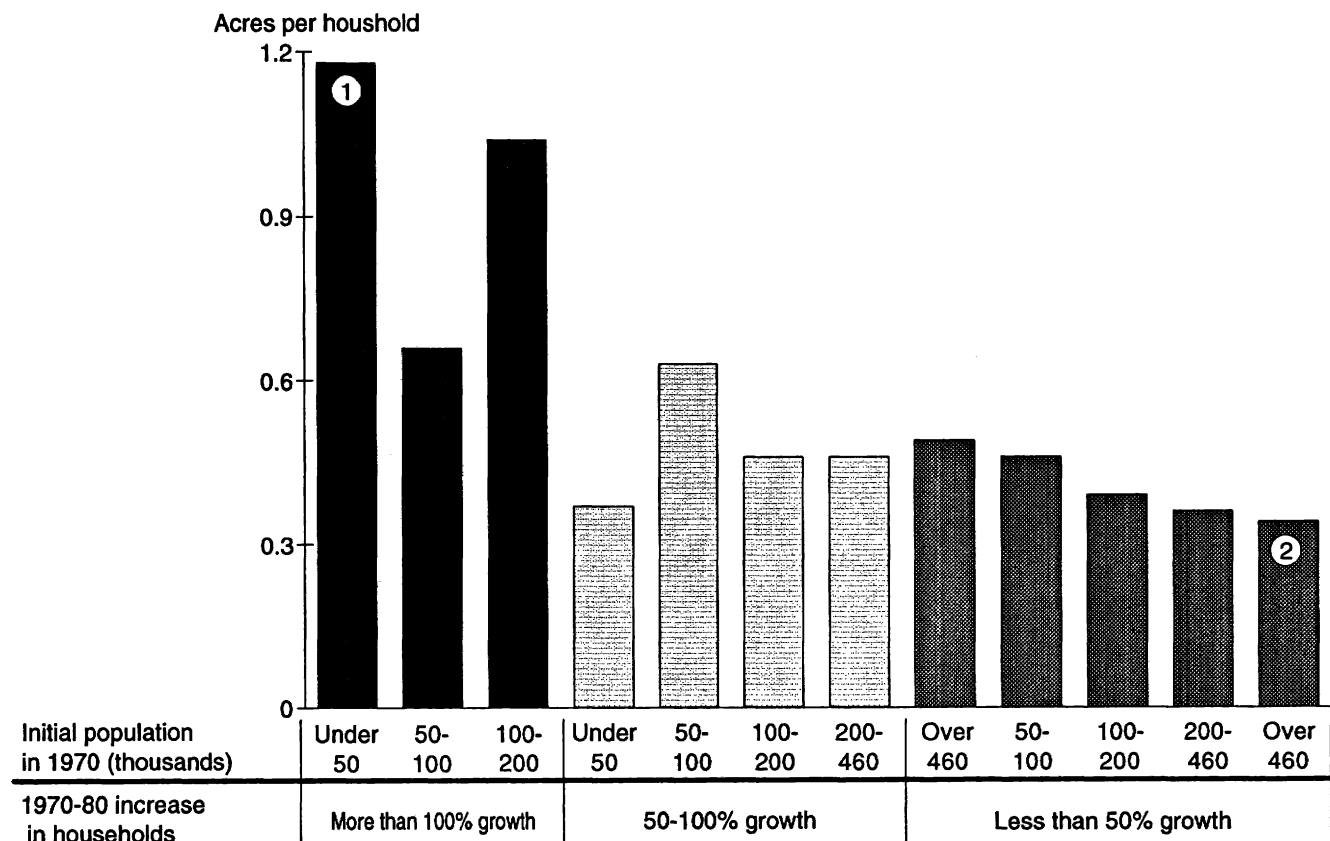
Counties use less land per added household as they continue to grow. Fast-growth counties in the early growth stages--those with fewer than 50,000 people--converted 1.18 acres per household but accounted for only 10 percent of fast-growth county urban conversion.

Counties in later growth stages--those with more than 460,000 people and slower growth in household numbers--converted 0.34-0.36 acre per new household but accounted for 24 percent of fast-growth county urban land conversion. The fastest growing counties had the lowest initial average population and the smallest initial household size.

Figure 19

Urban conversion by growth stage, fast-growth counties, 1970-80

Counties that grew faster than 100 percent in population added as much as 1.18 acres per household to urban area, while those that grew less than 50 percent added about one-third to one-half acre.



1. Fast-growth counties with fewer than 50,000 people in 1970 and rapid growth in household numbers converted 1.18 acres for each new household but accounted for only 10 percent of fast-growth county urbanization.
2. Counties in later growth stages--those with more than 460,000 people and slower growth in household numbers--converted 0.34 acre per new household but accounted for 24 percent of fast-growth county urbanization.

Source: Heimlich and Vesterby, 1992.

Urban Land Area Expanded the Most in the Southeast and Southwest

Fast-growth counties were located in 33 States, but 40 percent were located in California, Florida, and Texas. Urban land expanded at a higher rate (acres per household) in the Southeast. The Pacific region had the lowest rate.

Between 1970 and 1980, the U.S. population rose by 23 million (11 percent) to 226.5 million. The warmer Southeast and Southwest regions had a larger proportion of the population increase than did the North and Central Plains regions. The population movement from interior to coastal environments continued with a net increase of 10 million people. By 1980, half of the U.S. population lived within 50 miles of coastal shorelines (USDC, 1989b).

Urban Land Conversion Was Greater in Some Areas of the Country Than in Others

Sun Belt counties added the most urban land and used the most land for each new household. For example, there was a 73-percent increase in households in the Southwest compared with 60 percent in the Pacific region (fig. 20). The largest percentage increases in urban area were in the

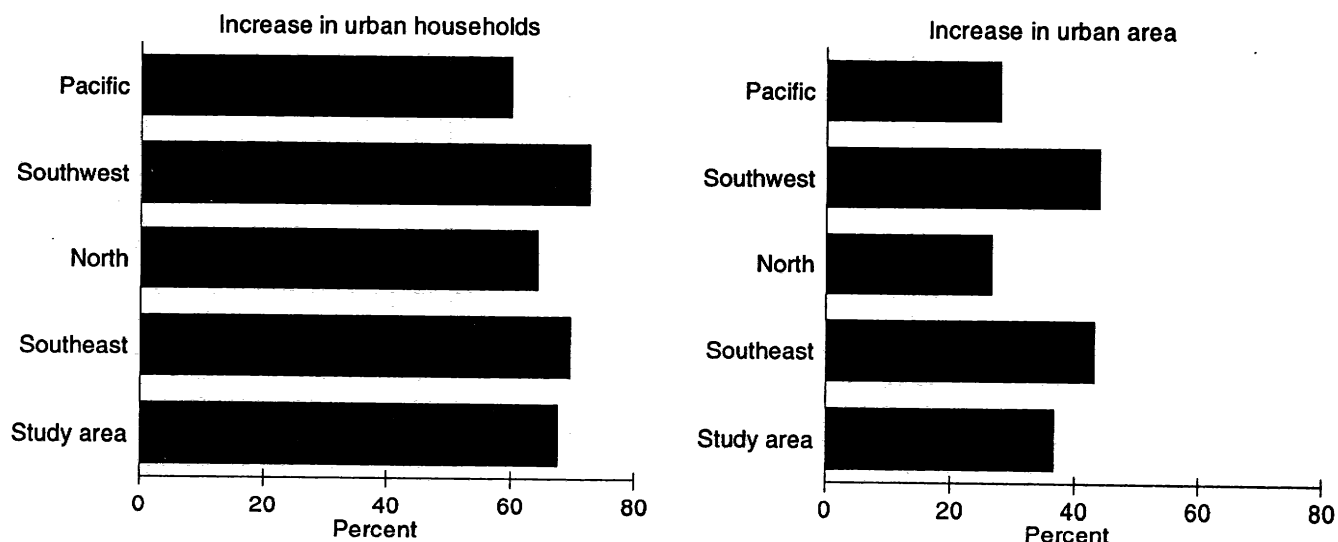
Southwest and Southeast. Counties in the Southeast showed a slightly larger marginal rate of urban conversion, 0.54 acre per new household. The Pacific region had the lowest rate, 0.40 acre per new household (table 11).

Though small, State and regional differences in rates of loss of agricultural land relate to an important characteristic of land use transition in fast-growth areas. Since production of different agricultural commodities is not evenly distributed nationally and neither is growth in urban uses, production of agricultural commodities located predominately in fast-growth areas will be affected more than production of those grown primarily in rural areas. For example, vegetables, fruits, nursery stock, and greenhouse products tend to be grown more in highly populated, fast-growing areas and are affected more by urbanization (Vesterby and Krupa, 1993).

Figure 20

Household and urban area increase, fast-growth counties, 1970-80

Households and urban area increased more in the Southwest and Southeast



Source: USDC, 1983, 1972; Vesterby, 1988d.

Table 11--Regional increases in households and urban area, fast-growth counties, 1970-80

The Pacific region had the lowest rate of urban conversion per new household.

| Region | Expansion in urban area | Increase in households | Gross urban conversion per new household |
|-----------------------------|----------------------------|---------------------------|---|
| | <i>1,000 acres</i> | <i>1,000</i> | <i>Acres per household</i> |
| North | 337 | 690 | 0.49 |
| Pacific | 434 | 1,075 | .40 |
| Southeast | 875 | 1,626 | .54 |
| Southwest | 815 | 1,668 | .49 |
| Central Plains ¹ | 0 | 0 | 0 |
| U.S. total | 2,461 | 5,059 | .49 |

¹The Central Plains had no fast-growth counties in the 1970's.

Source: USDC, 1983,1972; Vesterby, 1988d.

Expected Household Growth Would Increase Urban Area 15 Percent by 2000, but Would Not Significantly Reduce Cropland

If each household in fast-growth areas continues to use about one-half acre, by 2000 these households would annually require 860,000 acres. If other areas add 1 acre per household, by 2000 urban area would expand to 66 million acres. Cropland would be reduced by only about 2 percent.

If an assumption is made that the rate of land conversion continues at rates observed since 1960, then U.S. household growth would annually add about 860,000 acres of urban area until 2000. Rates of urban conversion per household added were constant in fast-growth areas between 1960 and 1980. If each new household projected from 1990 to 2000 in fast-growth areas adds 0.5 acre of urban land and if each new household in other areas adds 1 acre, urban area would expand from 57 million acres in 1987 to about 66 million acres by 2000 (fig. 21).

A maximum cropland loss scenario can be constructed by assuming cropland to be the only source of land for urban development. If cropland supplied all the expected new urban land, the cropland base in 2000 would be reduced only about 2 percent from 1990 levels (fig. 22). The remaining area devoted to cropland in 2000 would still be about the same as in 1982 because of new

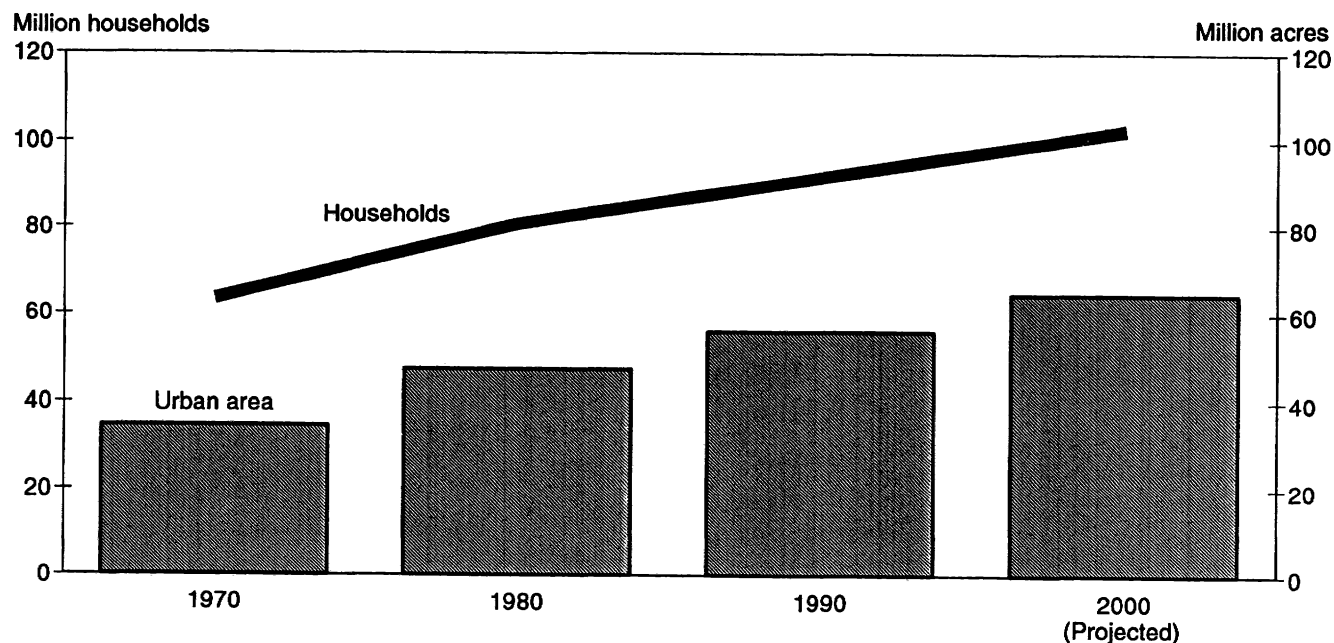
land brought into production between 1982 and 1990. In reality, that scenario is unlikely because it has been shown that only about a third of urban land comes from cropland. The rest comes from forest land and rangeland with small amounts taken out of miscellaneous uses.

High commodity prices have historically brought more cropland into production. In the future, some new cropland would be converted from forest and range uses. An estimated 35 million acres have high potential for crop use and 117 million more have medium potential (Hexem and Krupa, 1987; USDA, 1987). Also, crop production per acre has gained nearly every year for the last 40 years (fig. 23). Productivity has doubled since 1949. Future cropland losses would likely be partially offset by productivity gains. Food and fiber production should be sufficient to meet demand well into the next century.

Figure 21

Household and urban area projections, 1970-2000

Expected household growth would increase urban area 15 percent by 2000.

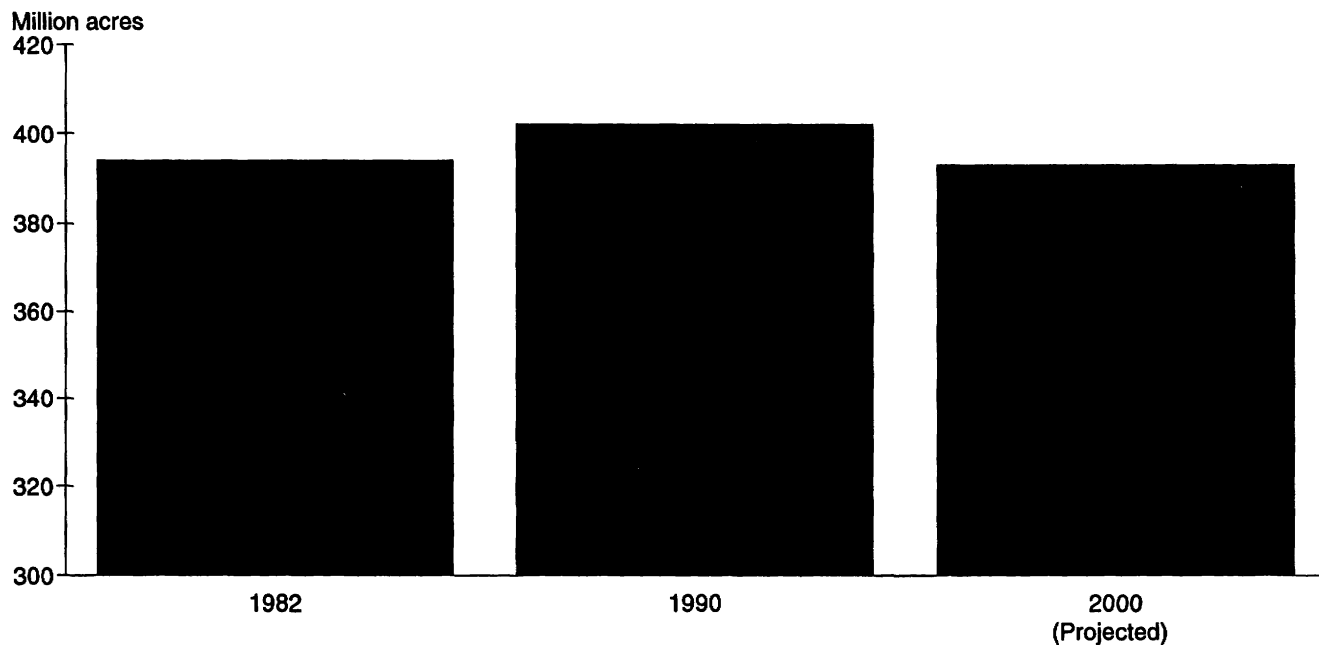


Sources: Heimlich and others, 1991; USDC, 1989b.

Figure 22

Projected change in cropland from urbanization, 1982-2000

Projected urban growth will not reduce cropland significantly.



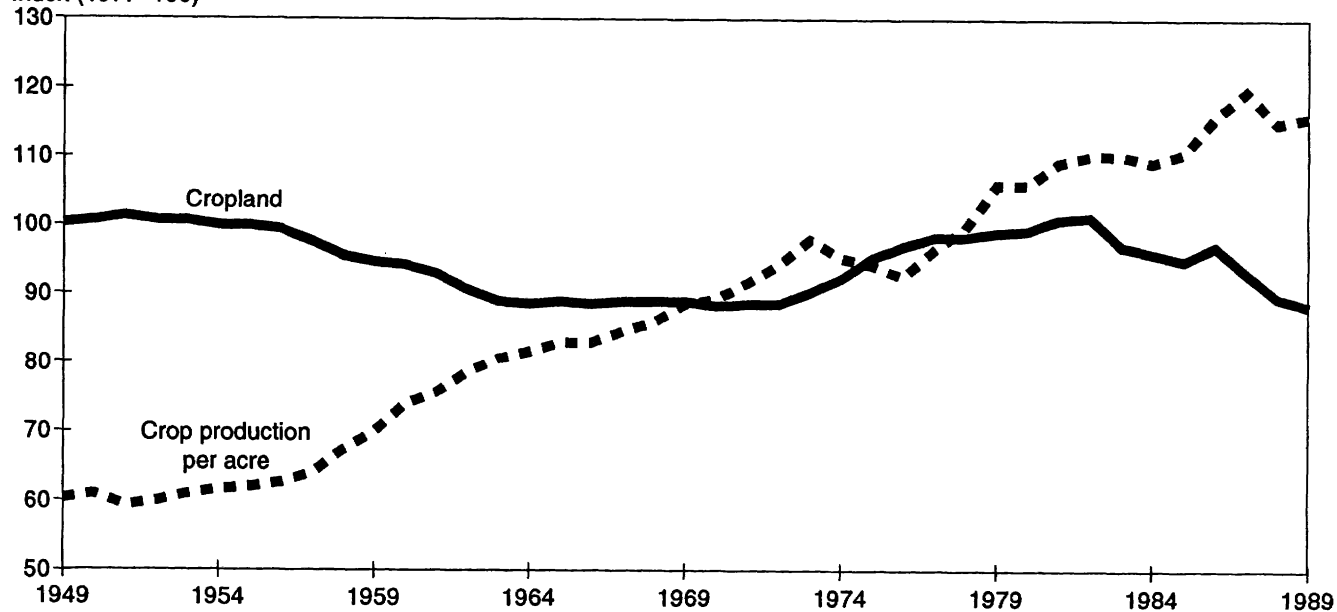
Source: USDA, 1991.

Figure 23

Cropland and productivity, 1949-89

Crop production per acre has gained nearly every year for the last 40 years.

Index (1977=100)*



* Three-year moving average. Source: USDA, 1991.

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Appendix table 1--Sample points, 135 fast-growth counties, 1970-80

| Land use | Land use ¹ | | | | | | | | | | | | | | | | | 1970 total |
|---------------|-----------------------|-----|-----|-----|-------|-----|----|-------|----|-------|-----|-----|-----|-----------------|----|-----|--------|------------|
| | 11 | 12 | 14 | 16 | 21 | 22 | 23 | 30 | 31 | 40 | 50 | 60 | 70 | 76 ² | CC | PC | NI | |
| Sample points | | | | | | | | | | | | | | | | | | |
| 11 | 650 | 2 | - | 1 | - | - | - | - | 2 | - | - | - | - | 1 | - | 12 | - | 668 |
| 12 | - | 183 | - | - | 1 | - | - | 1 | - | - | - | - | - | 1 | - | - | - | 186 |
| 14 | 1 | - | 163 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | 166 |
| 16 | 9 | 4 | - | 124 | - | - | - | - | 1 | 1 | - | - | - | 1 | - | 5 | - | 145 |
| 21 | 108 | 27 | 1 | 11 | 3,692 | 42 | 9 | 45 | 13 | 22 | 7 | 1 | 9 | 26 | - | 44 | - | 4,057 |
| 22 | 9 | 1 | 1 | 1 | 7 | 233 | - | 1 | 1 | - | - | - | - | - | - | - | - | 254 |
| 23 | - | - | - | - | 2 | - | 20 | - | - | - | - | - | - | - | - | 1 | - | 23 |
| 30 | 69 | 17 | 2 | 7 | 107 | 19 | 2 | 4,251 | - | 47 | 12 | - | 16 | 33 | - | 127 | - | 4,709 |
| 31 | 3 | 1 | - | - | 3 | - | - | - | 36 | 9 | 2 | - | 0 | 1 | - | - | - | 55 |
| 40 | 83 | 9 | 6 | 5 | 27 | 1 | 1 | 28 | 6 | 3,596 | 7 | - | 3 | 17 | - | 75 | - | 3,864 |
| 50 | 1 | 1 | - | - | - | - | - | 2 | 1 | 1 | 114 | 3 | 6 | - | - | 3 | - | 132 |
| 60 | 8 | - | 3 | 3 | 12 | 1 | 1 | 9 | - | 7 | 5 | 810 | 3 | 5 | 1 | 12 | - | 880 |
| 70 | - | - | - | - | 2 | 1 | - | 15 | 1 | 1 | 9 | - | 177 | - | - | 27 | - | 233 |
| 76 | 43 | 7 | 2 | 2 | 3 | - | - | 4 | - | - | 2 | - | - | 3 | - | 1 | - | 67 |
| CC/SC | 5 | 2 | - | - | 8 | 1 | - | 40 | - | 28 | 1 | 8 | 5 | 2 | - | 4 | - | 104 |
| PC | 25 | 9 | 7 | 2 | 80 | 6 | 1 | 394 | - | 152 | 4 | 18 | 15 | 3 | - | 328 | - | 1,044 |
| FL/IR | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 13,785 | 13,785 |
| 1980 | | | | | | | | | | | | | | | | | | |
| Total | 1,014 | 263 | 185 | 156 | 3,944 | 304 | 34 | 4,790 | 61 | 3,864 | 163 | 840 | 234 | 93 | 1 | 641 | 13,785 | 30,372 |

- = No observation.

CC/SC = Cloud cover/snow cover.

PC = Photo coverage lacking.

FL/IR = Federal land and Indian Reservations.

NI = Sample points were plotted but not interpreted for Federal land and Indian Reservations at the late date (see text).

Water cover, 614 sample points, was deleted from the study (see text).

¹Land uses 11 through 76 are described in the text, "Land Use Classification Legend." A detailed description, including the interpretation decision rules, is in Freed and Jones, 1988.

²Land Use 76, transition, is land on which change is in progress, such as forest land being cleared for some indiscernible future use. Transition land was sometimes combined with urban uses since most early date transition land was converted to urban uses.

Source: Vesterby, 1988d.

Appendix table 2--Area by land use, 135 fast-growth counties, 1970-80

| Land use | Land use ¹ | | | | | | | | | | | | | | | Sub-total | CC | PC | NI | 1970 total |
|-------------|-----------------------|-------|-----|-----|--------|-------|-----|--------|-----|--------|-----|-------|-------|-----------------|--------|-----------|-------|--------|---------|------------|
| | 11 | 12 | 14 | 16 | 21 | 22 | 23 | 30 | 31 | 40 | 50 | 60 | 70 | 76 ² | | | | | | |
| 1,000 acres | | | | | | | | | | | | | | | | | | | | |
| 11 | 3,468 | 11 | - | 6 | - | - | - | - | 11 | - | - | - | - | 5 | 3,500 | - | 64 | - | 3,564 | |
| 12 | - | 985 | - | - | 5 | - | - | 5 | - | - | - | - | - | 6 | 1,001 | - | - | - | 1,001 | |
| 14 | 5 | - | 876 | - | - | - | - | - | - | - | - | - | - | - | 880 | - | 11 | - | 891 | |
| 16 | 48 | 21 | - | 664 | - | - | - | - | 6 | 6 | - | - | - | 5 | 750 | - | 27 | - | 776 | |
| 21 | 580 | 146 | 5 | 59 | 19,795 | 225 | 48 | 242 | 66 | 119 | 38 | 6 | 48 | 140 | 21,517 | - | 239 | - | 21,756 | |
| 22 | 47 | 5 | 5 | 6 | 37 | 1,238 | - | 5 | 5 | - | - | - | - | - | 1,349 | - | - | - | 1,349 | |
| 23 | - | - | - | - | 11 | - | 108 | - | - | - | - | - | - | - | 119 | - | 6 | - | 124 | |
| 30 | 371 | 91 | 11 | 38 | 577 | 102 | 11 | 22,895 | - | 255 | 65 | - | 87 | 176 | 24,678 | - | 682 | - | 25,361 | |
| 31 | 16 | 4 | - | - | 15 | - | - | - | 188 | 48 | 10 | - | - | 5 | 287 | - | - | - | 287 | |
| 40 | 447 | 49 | 33 | 27 | 146 | 6 | 5 | 152 | 31 | 19,343 | 38 | - | 16 | 91 | 20,382 | - | 402 | - | 20,784 | |
| 50 | 5 | 6 | - | - | - | - | - | 11 | 6 | 6 | 610 | 16 | 30 | - | 690 | - | 16 | - | 705 | |
| 60 | 42 | - | 16 | 16 | 65 | 5 | 5 | 48 | - | 36 | 27 | 4,319 | 16 | 26 | 4,621 | 5 | 64 | - | 4,689 | |
| 70 | - | - | - | - | 11 | 6 | - | 80 | 5 | 5 | 47 | - | 949 | - | 1,103 | - | 146 | - | 1,249 | |
| 76 | 231 | 36 | 11 | 11 | 16 | - | - | 21 | - | - | 11 | - | - | 16 | 354 | - | 5 | - | 359 | |
| Sub-total | 5,258 | 1,354 | 957 | 826 | 20,679 | 1,581 | 177 | 23,460 | 317 | 19,818 | 846 | 4,340 | 1,147 | 470 | 81,230 | - | - | - | - | |
| CC/SC | 26 | 11 | - | - | 43 | 6 | - | 215 | - | 150 | 5 | 43 | 26 | 10 | - | - | 22 | - | 557 | |
| PC | 131 | 49 | 38 | 11 | 428 | 31 | 5 | 2,126 | - | 817 | 22 | 101 | 80 | 17 | - | - | 1,777 | - | 5,633 | |
| FL/IR | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 74,278 | 74,278 | |
| 1980 | | | | | | | | | | | | | | | | | | | | |
| Total | 5,415 | 1,414 | 995 | 837 | 21,150 | 1,618 | 182 | 25,800 | 317 | 20,785 | 873 | 4,485 | 1,253 | 497 | - | 5 | 3,459 | 74,278 | 163,363 | |

- = No observation.

CC/SC = Cloud cover/snow cover.

PC = Photo coverage lacking.

FL/IR = Federal land and Indian Reservations.

NI = Sample points were plotted but not interpreted for Federal land and Indian Reservations at the late date (see text).

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Source: Vesterby, 1988d.



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